# Estimate of BT's Equity Beta

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# Contents

# 1  Introduction

Ofcom has asked us to update our estimate of the equity beta for British Telecom.[1] We understand that Ofcom intends to use the estimate to inform its decision on the level of access charges for the local loop and other regulated wholesale services. We perform various analyses and present beta estimates for BT.

We also examine betas for two reference samples. One reference sample comprises the five other publicly traded UK utilities, comprising National Grid (the gas and electricity transmission system operator) and four water utilities (United Utilities, Severn Trent, Pennon Group and Northumbria Water). All of the companies in the UK utility peer group provide essential services and are subject to price regulation. A utility peer group subject to UK price regulation represents the most obvious benchmark against which to compare the results of our beta calculations for BT and against which to assess the relative riskiness of BT's regulated activities. Indeed, the UK utility peer group was recently cited in a decision by the Competition Appeals Tribunal, when it assessed the beta for BT's local loop and regulated wholesale services.[2]

A second reference sample comprises large liquidly traded US telecommunications stocks. Some of the companies in our US sample focus primarily on wireline services, including retail and wholesale activities dependant on the local loop (for example the provision of local telephone services to customers and the provision of broadband services through the local loop). In contrast, others like US Cellular focus on wireless operations to the exclusion of wireline. Still others, usually the large cap telecommunications companies such as AT&T and Verizon have substantial wireline and wireless activities across the US. The US telecommunications sample is interesting in part because it helps identify whether distinct risks apply to activities dependant on the local loop as opposed to wireless activities. A beta estimate for US wireline services would be informative for BT's local loop business.

Several important caveats apply when interpreting results:

1. None of the companies examined provide regulated access to the local loop alone, and as a result due consideration is required before direct application of any of our beta estimates to BT's local loop activities. Even the observed beta for BT's stock price may not apply directly to its local loop activities. As a corporation, BT is involved in numerous activities other than the provision of local loop access. For example, retail of telecommunications services accounted for 32% of BT's 2009 revenues and 25% of 2009 EBITDA. Likewise, not even any of the wireline-only US telecommunications companies provide only regulated access to the local loop, but engage in a variety of retail activities such as the sale of broadband access. For their part, similarity in regulatory regimes is what makes the examination of the other

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[1] We last provided an update of BT's equity beta in March 2009. See *Updated Estimate of BT's Equity Beta* (March 2009), available on Ofcom's website.

[2] Competition Commission Determination, *The Carphone Warehouse Group plc v Office of Communications*, Case 1111/3/3/09, 31 August 2010, p. 2-81.

UK utilities interesting. Yet despite similarity in regulatory regime, the risk associated with local telecommunications services may differ from those related to the provision of energy or water. Without further analysis, it remains unclear the extent to which the observed betas for BT and the reference samples reflect the particular risks associated with local loop access in the UK.

2. While we examine the statistical robustness of the observed betas, we do not assess in detail the broad effect of the credit crisis on the observed betas nor do we assess whether the immediate past could be a reliable guide to the future period of interest to Ofcom. This issue needs further work before we could make any firm recommendations concerning the relevance of the beta estimates presented in this report to the calculation of mobile call termination fees.

In this report, we adopt the same methodology as in other previous engagements for Ofcom.[3] We calculate daily returns from holding stock in BT and each of the other companies considered, and from holding a broad market index. We examine data for two market indices: the FTSE All-Share reflecting all stocks trading on the London Stock Exchange and the FTSE All-World reflecting a large proportion of publicly traded stocks around the world. As is standard, we perform a regression of the daily returns on each company against the daily returns on the market index. The regression coefficient is the equity beta. We use market data up to and including October 27 2010.

Previous work for Ofcom examined beta estimation methods.[4] One issue concerned the frequency with which to measure stock returns: whether to use daily, weekly or even monthly returns. Analysts might use weekly or monthly returns if there is a concern about the liquidity of stock trading. No such concern exists in this case. All of the major telecoms stocks and utilities under examination are amongst the most liquid stocks around. All of our estimates therefore focus on daily returns. Another methodological choice relates to the duration of the data window. We focus on a two-year window in this report, while also reporting the results from a one-year window. Two-years provides a sizeable sample of daily stock returns without extending so far back in time as to include data from periods before the four companies made significant operational changes.

Chapter 2 presents beta estimates for BT, the UK utility reference sample and the US telecoms sample. Chapter 3 reports the results of several tests of the statistical reliability of the beta estimates for BT and the UK utility sample.

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[3] See, for example, *Updated Estimate of BT's Equity Beta* (October 2008), *An Estimate of the Equity Beta of BskyB* (March 2009), and *Estimate of Equity Beta for UK Mobile Owners* (December 2009).

[4] See *Issues in beta estimation for UK mobile operators*, July 2002.

## 2 Equity beta estimates

### 2.1 Up-to-date estimates

Table 1 reports up-to-date beta estimates for BT and the UK utility reference sample. All of the estimates rely on daily return data. We report separate one and two year beta estimates as well as separate estimates against the two market indices. A one-year beta relies on the previous year of trading activity. A two-year beta relies on the previous two years. All of the various estimates reflect data up to and including September 30 2010.

**Table 1: Up-to-date beta estimates[5]**

| | 1 Yr | | | | 2 Yr | | | |
|---|---|---|---|---|---|---|---|---|
| | Beta | SE | Low | High | Beta | SE | Low | High |
| *BT* | | | | | | | | |
| All World | 0.86 | 0.12 | 0.63 | 1.09 | 0.67 | 0.08 | 0.51 | 0.83 |
| All Share | 0.96 | 0.09 | 0.79 | 1.14 | 0.84 | 0.07 | 0.70 | 0.98 |
| ***UK Utility Peer Group*** | | | | | | | | |
| *National Grid* | | | | | | | | |
| All World | 0.53 | 0.07 | 0.39 | 0.66 | 0.40 | 0.05 | 0.30 | 0.50 |
| All Share | 0.52 | 0.05 | 0.41 | 0.62 | 0.62 | 0.04 | 0.54 | 0.70 |
| *Northumbrian Water* | | | | | | | | |
| All World | 0.45 | 0.09 | 0.27 | 0.63 | 0.34 | 0.05 | 0.24 | 0.44 |
| All Share | 0.46 | 0.07 | 0.32 | 0.61 | 0.53 | 0.04 | 0.44 | 0.61 |
| *Pennon Group* | | | | | | | | |
| All World | 0.45 | 0.08 | 0.30 | 0.60 | 0.42 | 0.06 | 0.31 | 0.53 |
| All Share | 0.47 | 0.06 | 0.35 | 0.59 | 0.60 | 0.05 | 0.51 | 0.69 |
| *Severn Trent* | | | | | | | | |
| All World | 0.42 | 0.07 | 0.28 | 0.55 | 0.39 | 0.05 | 0.30 | 0.49 |
| All Share | 0.38 | 0.06 | 0.26 | 0.49 | 0.53 | 0.04 | 0.45 | 0.61 |
| *United Utilities* | | | | | | | | |
| All World | 0.42 | 0.07 | 0.28 | 0.55 | 0.40 | 0.04 | 0.31 | 0.49 |
| All Share | 0.40 | 0.06 | 0.29 | 0.51 | 0.54 | 0.04 | 0.47 | 0.61 |

The most recent data indicate little change in the level of BT's equity beta. Against the FTSE All-Share, we estimate an up-to-date one-year equity beta of 0.96, compared with our estimate of 0.85 in March 2009. We estimate an up-to-date two–year equity beta of 0.84, compared with our estimate of 0.85 in March 2009. The slight changes in the level of the raw equity betas are well within the range of statistical error. BT equity betas against the FTSE All-World have also seen little change since March 2009.

Figure 1 illustrates the development of BT's equity beta against the FTSE All-Share over time. The plot keeps the duration of the beta estimation window constant through time. It simply shifts the one or two-year data window forward as time passes. It illustrates the relative stability of the two-year BT equity beta over the past two years, even while overall price volatility spiked dramatically upwards at the end of 2008 and is only now returning to normal levels. Although the two-year beta remained stable, both the rolling sixth month and one-year betas display some volatility. The one year beta has

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[5] Low and high refer to the 95% confidence interval and not to the lowest and highest one and two-year betas observed throughout the year.

varied between 0.76 and 0.99, while the sixth month estimate declined to as low as 0.52 before climbing more recently to 1.13.

**Figure 1: BT rolling betas**



Table 1 highlights that BT's equity beta comes in higher than all of the other UK utilities. BT's one-year equity beta is now more than double the average of the other UK utilities (0.96 vs 0.45), while the two-year beta remains almost a third higher (0.84 vs 0.56). The gap between BT and the other utilities has widened over the past two years. While BT's equity beta has remained stable, only the two-year estimates for the other utilities have displayed some degree of stability. The effect of the credit crisis maybe apparent.

Figure 2 to Figure 6 plot one and two year betas for the other UK utilities against the FTSE All-Share. National Grid, Pennon Group, Severn Trent and United Utilities see a large wobble in the equity beta during the last few months of 2008. Then in 2009, the one-year estimates fall off dramatically towards the end of the year. The timing may reflect movement of the end of the data window past autumn 2008 and the climax of the credit crisis. The step declines for National Grid, Severn Trent and United Utilities are roughly two standard deviations. The one-year betas do not yet show any sign of a return to previous levels, although the sixth month beta for National Grid has shown some upward movement. The effect is somewhat less extreme for Northumbrian Water and Pennon Group.

Underlying the recent downward trend in the one-year betas may be a step change in investors' risk perception of utilities since the collapse of Lehman, as part of a fundamental re-evaluation of risk and a "flight to safety". Of course, the change in risk perceptions will flow through slowly to the two-year beta estimate as more recent post-Lehman data replaces pre-crisis data. Nevertheless we would observe any effect much sooner in the one-year estimates. At first glance, the step change in the one-year utility

sample estimates appears perfectly consistent with this explanation. Yet we still await the effect flowing through to the two-year utility numbers. If the step-change in perceptions were real, we would expect to see it flow through to the two-year betas by the end of the year and the passage of the two-year data window past autumn 2008.

What is striking is the contrasting lack of an effect at BT. Both BT's one and two year betas have remained rock steady, while the betas for the other utilities' have jumped around and declined. Under the credit crisis explanation, we would have to attribute the lack of any effect for BT to a lack of investor confidence. Perhaps they did not consider BT a "safe haven" in exactly the same manner as National Grid or some of the water companies in part because of outstanding uncertainty surrounding pension funding and the poor performance of BT's global services division.[6]

Of course, the drop in the one-year betas for National Grid and some of the other utilities may reflect no more than noise in the data, for which we have at least some precedent. In the past ten years, we have seen one-year betas shift by more than twice the standard error and the one-year and two-year beta estimates parting company. Yet the current gap between the one and two-year estimates seems relatively large and persistent. In section three, we identify which particular data points exert the greatest influence on the one and two year beta estimates and investigate the impact of those points on the estimates. We find that the standard OLS betas are broadly stable to the exclusion or underweighting of influential data points.

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[6] We note that throughout the last two years the average daily volatility of BT's share price remained larger than the average daily price volatility for the market as a whole. In contrast, the daily price volatility for United Utilities declined to match that of the overall market.
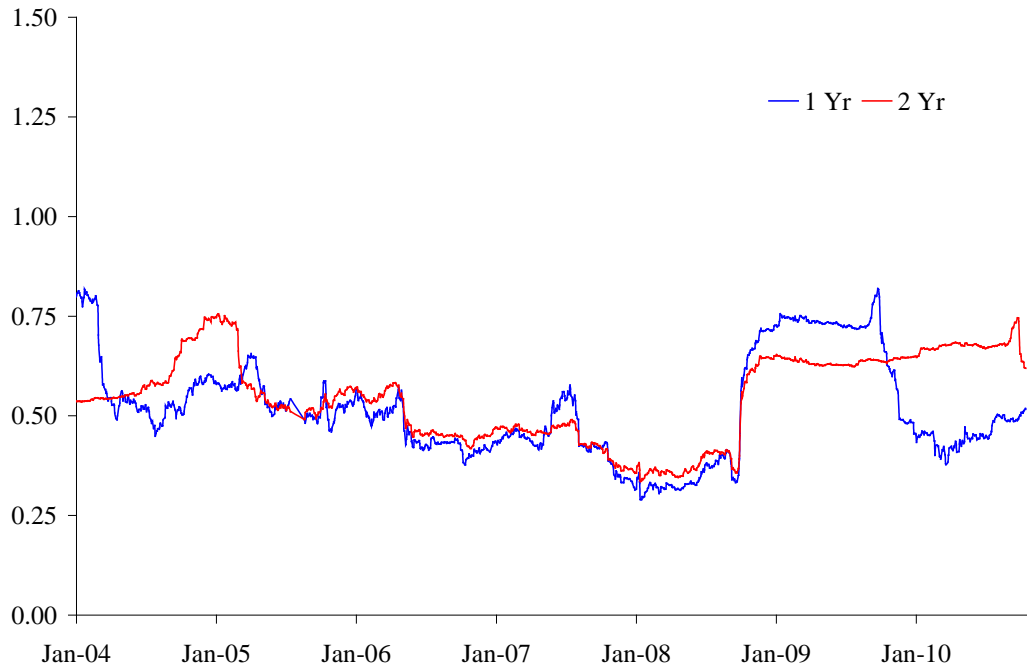
**Figure 2: National Grid rolling betas**



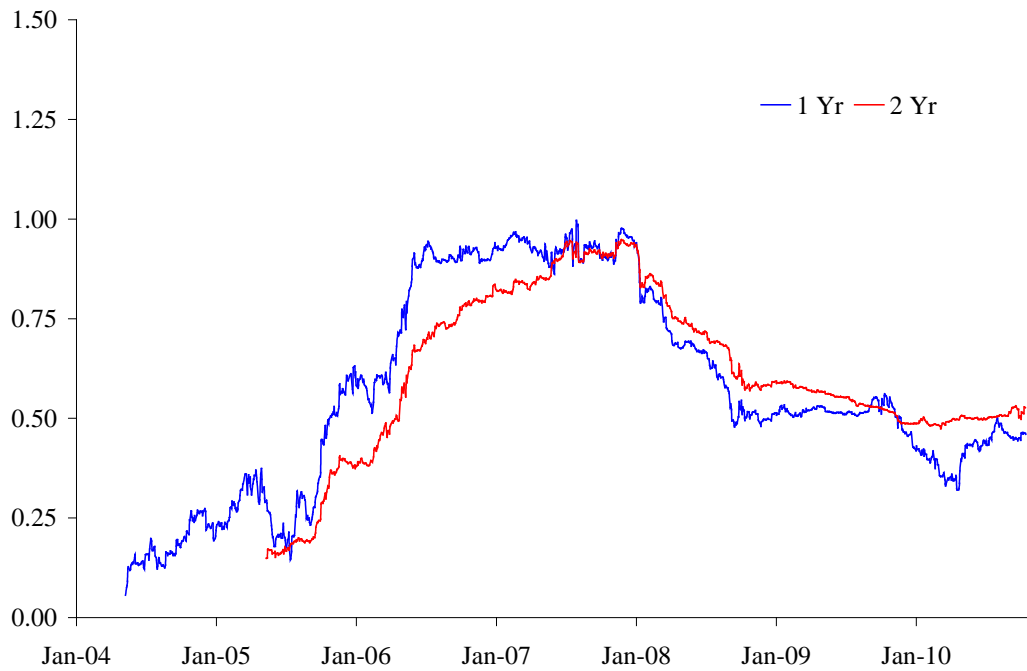**Figure 3: Northumbrian Water rolling betas**

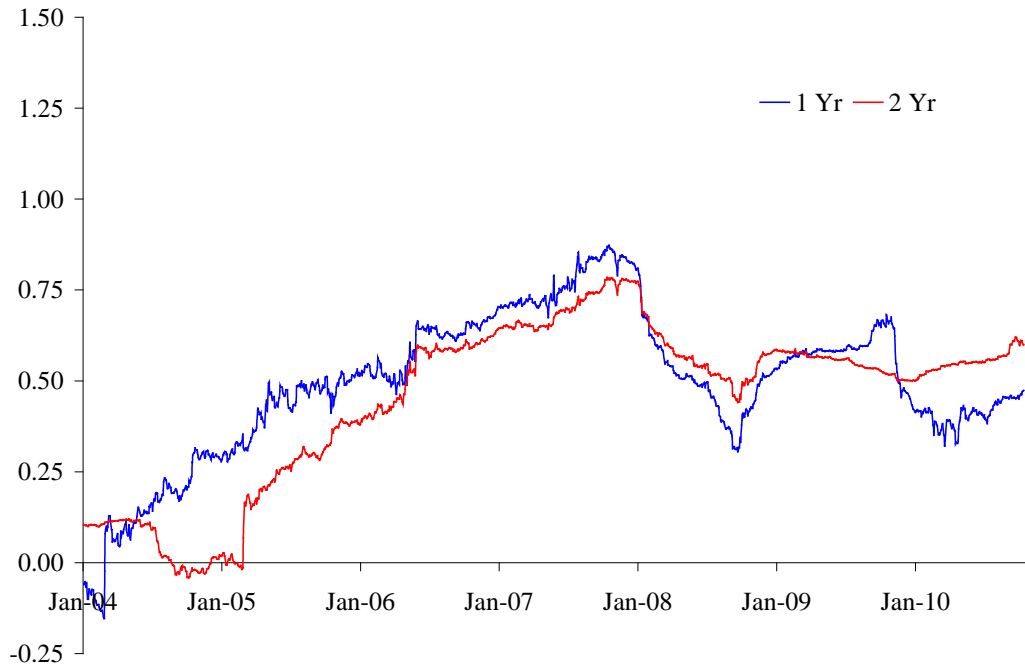**Figure 4: Pennon Group rolling betas**



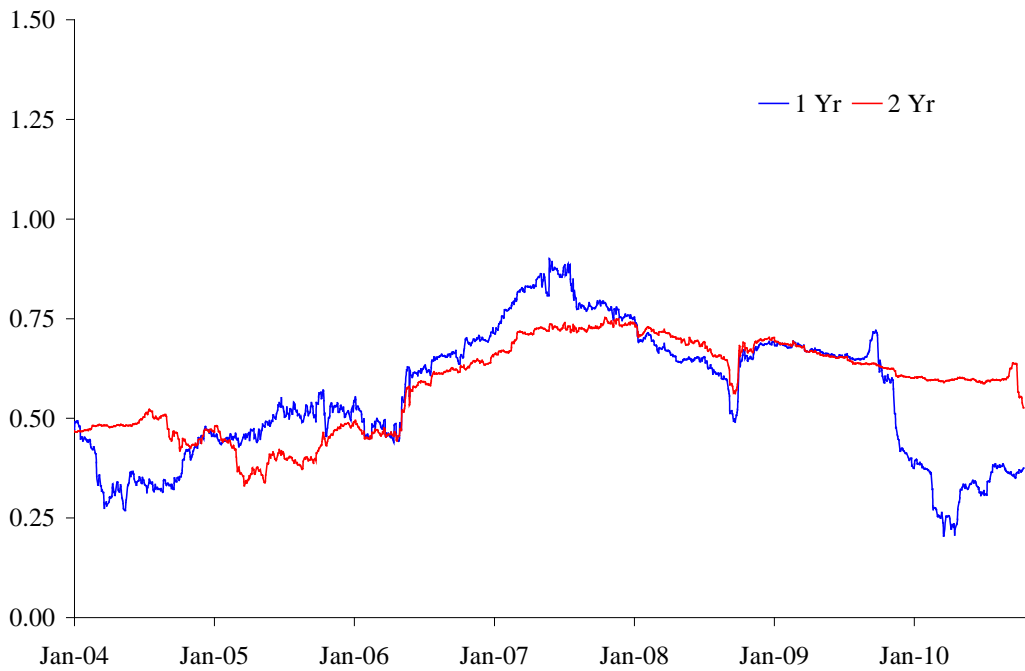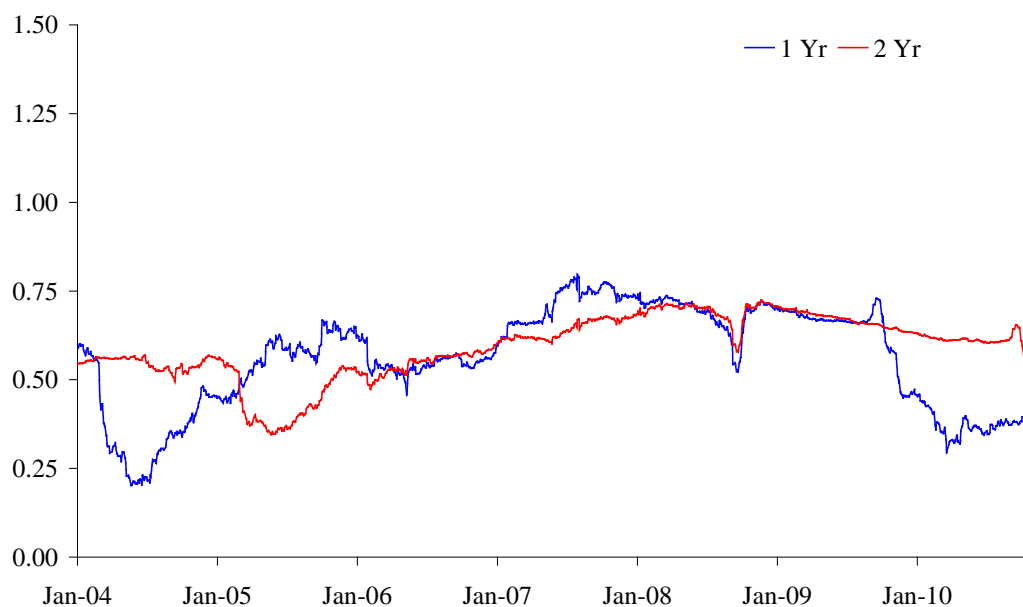**Figure 5: Severn Trent rolling betas**

**Figure 6: United Utilities rolling betas**



An alternative explanation remains consistent with the observed patterns over time. Perhaps National Grid and the water utilities perform differently in normal economic conditions than in crises. For example, investors might expect utility performance to be consistent with a beta of 0.75 during normal times, but then during abnormal times, to outperform the market consistent with a beta of only 0.4. Performing at 0.75 during normal times and 0.4 during crises would result in overall utility returns greater than implied by a consistent 0.4 beta level measured throughout difficult circumstances. In effect, investors might expect utilities to go up with the market during normal times at 0.75, but then during bad times to go down with the market to less extent, consistent with only a 0.4 beta. If this were the case, investors would expect higher overall returns from utilities than predicted by the current one-year beta of 0.4, while it might also suggest that the one-year betas will trend upwards as investors become more confident about the state of the economy.

### 2.2 Financial leverage

Equity risk reflects the combination of underlying business risk (to do with the variability of revenues and the extent of fixed costs) and financial risk (to do with the presence of fixed debt obligations). Other things equal, the more debt a company has outstanding, the greater the equity risk and the higher the equity beta. In general, extreme changes in financial leverage throughout the measurement window prompt the need for further analyses and checks.

We obtained data on the amount of debt outstanding for BT and each of the five publicly traded UK utilities between 2004 and the present. We obtained data from Bloomberg primarily, and filled in any remaining gaps with data from company annual and half-yearly reports and quarterly earnings announcements. We use the data to

estimate the companies' capital structures at various points in time between 2004 and the present. We focus on market values rather than book values, since market values better indicate earnings power. That being said, we follow the approach adopted in previous reports and assume that the market value of utility debt remained relatively close to its face value throughout the period in question.

This assumption appears reasonable given that BT as well as the five other UK utilities all maintained investment grade credit ratings throughout the measurement period. Nevertheless, a possible concern is whether the market price of BT's and the other UK utilities' debt diverged somewhat from face value during the height of the credit crisis. If a significant market-to-book difference emerged, then a failure to use market values could bias, probably upward, our estimates of the companies' financial leverage. For example, as credit spreads spiked during the credit crisis, the price on BT and other UK utility debt may have declined somewhat, reflecting investors' concerns about the prospects for the UK and world economy. Incorporating the reduced market price of the debt in the calculation would reduce the appearance of financial leverage. Overstating leverage could lead us to effectively understate BT's overall asset beta, since we would always expect leverage to add to the equity beta.

We check the potential impact of the financial crisis on financial leverage by estimating the market price of BT's debt. Much of BT's long-term debt is publicly traded. We obtained available data concerning debt prices and yields. The available data indicates that the market price of BT's debt has remained within 10% of its face-value since 2007. Market prices declined somewhat at the end of 2008 during the height of the crisis, but not to so large an extent as to seriously affect our estimates of financial leverage. Adjusting the amount of debt by less than 10% either way could have only a 2.5% impact on BT's apparent leverage ratio, and even less on the average leverage over an extended measurement window.

We do not check the market price of the debt of other UK and US comparables, in part because detailed trading data is unlikely to be available for some of the other companies, and in part because our calculations for BT indicate the reasonableness of our assumption about the value of high grade utility debt. Figure 7 plots our resulting estimates of financial leverage for the UK utility reference sample.

**Figure 7: UK utility financial leverage**
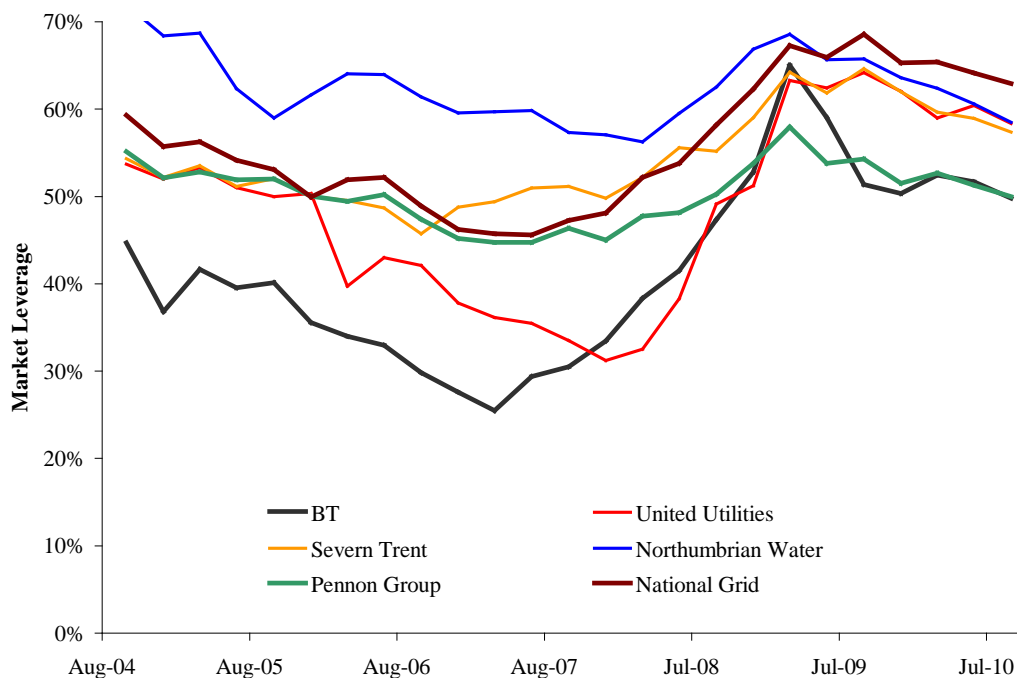


The black line in the figure indicates that BT has witnessed a substantial rise in leverage since 2007. BT maintained a relatively stable amount of debt over the period, even while its share price dropped dramatically during 2008. The same level of debt combined with less equity, so that leverage doubled to just over 60% by the end of 2008. The share price has since rebounded somewhat, but still remains at less than a half of its previous high. The share price rebound has prompted somewhat of a decline in BT's financial leverage. Of the other UK utility peer group, only United Utilities witnessed a similar swing in leverage during the recent measurement period.

A further table and figures explore the effect of financial leverage across BT and the UK utility reference sample. Table 2 reports equity beta estimates for BT and the utility sample assuming that all of the companies maintained only equity financing. We use two separate approaches to reliever the raw equity beta estimates. The first approach uses the simplest possible re-levering formula and assumes that the debt beta is zero.[7] The second approach follows the same approach but is more realistic in that it recognises some correlation between the returns to debt-holders and the broader economy. It assumes a debt beta of 0.15. Under both approaches, we estimate average leverage across the relevant measurement window. In other words, when focussing on one-year betas, we estimate average leverage across the one-year measurement window. When focussing on two-year betas, we estimate average leverage across the two-year measurement window. Figure 8 and Figure 9 then plot rolling one and two year asset for BT and the utility reference sample. They clearly illustrate the widening gap between BT and the other UK

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[7] We use a standard relevering formula (see *Principles of Corporate Finance* (8th edition), Brealey Myers and Allen, p. 518).

utilities since the onset of the credit crisis. A further figure illustrates the recent divergence between the one and two-year asset betas.

**Table 2: "Asset" betas**

| | 1 Year | | 2 Year | |
|---|---|---|---|---|
| | *β debt = 0* | *β debt = 0.15* | *β debt = 0* | *β debt = 0.15* |
| *BT* | | | | |
| All Share | 0.47 | 0.55 | 0.39 | 0.47 |
| All World | 0.42 | 0.50 | 0.31 | 0.39 |
| ***UK Utility Peer Group*** | | | | |
| *National Grid* | | | | |
| All Share | 0.18 | 0.28 | 0.22 | 0.32 |
| All World | 0.18 | 0.28 | 0.14 | 0.24 |
| *Northumbrian Water* | | | | |
| All Share | 0.17 | 0.27 | 0.19 | 0.29 |
| All World | 0.17 | 0.26 | 0.12 | 0.22 |
| *Pennon Group* | | | | |
| All Share | 0.23 | 0.31 | 0.28 | 0.36 |
| All World | 0.22 | 0.29 | 0.20 | 0.28 |
| *Severn Trent* | | | | |
| All Share | 0.15 | 0.24 | 0.21 | 0.30 |
| All World | 0.16 | 0.25 | 0.15 | 0.25 |
| *United Utilities* | | | | |
| All Share | 0.16 | 0.25 | 0.22 | 0.31 |
| All World | 0.16 | 0.25 | 0.16 | 0.25 |
| *Peer Group Average* | | | | |
| All Share | 0.18 | 0.27 | 0.22 | 0.31 |
| All World | 0.18 | 0.27 | 0.16 | 0.25 |

**Figure 8: One-year asset betas - FTSE All-Share**
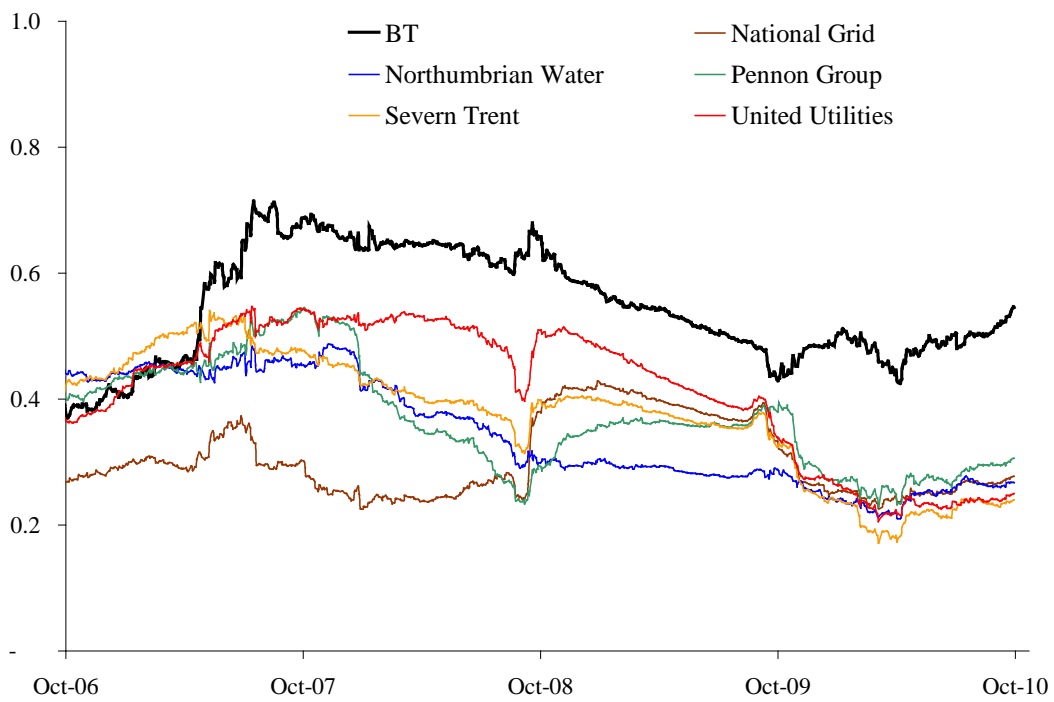


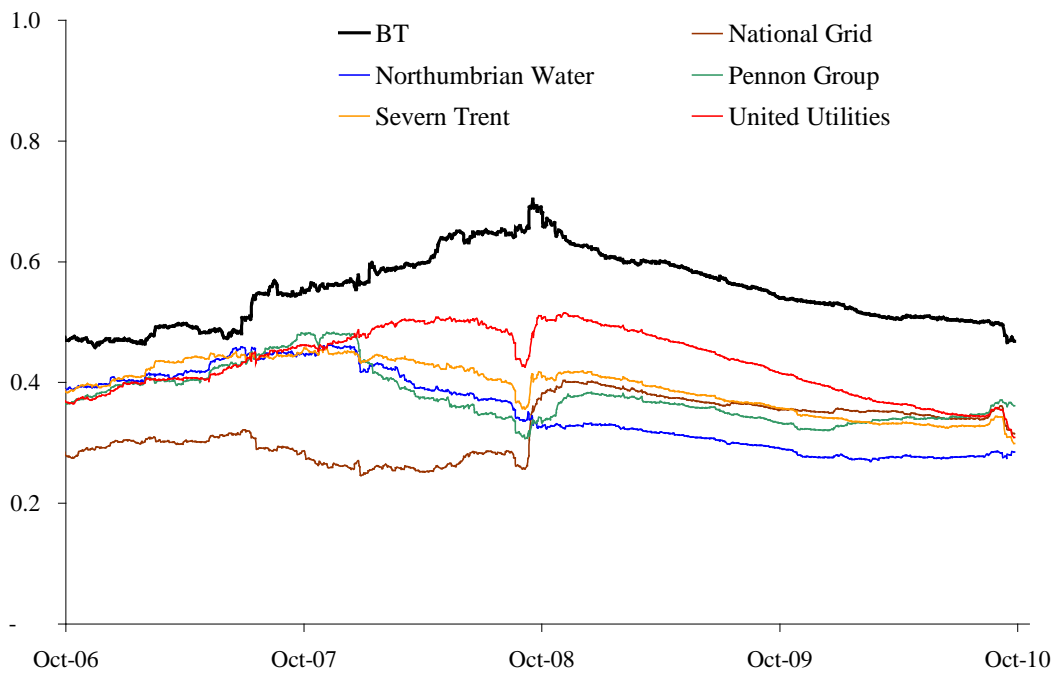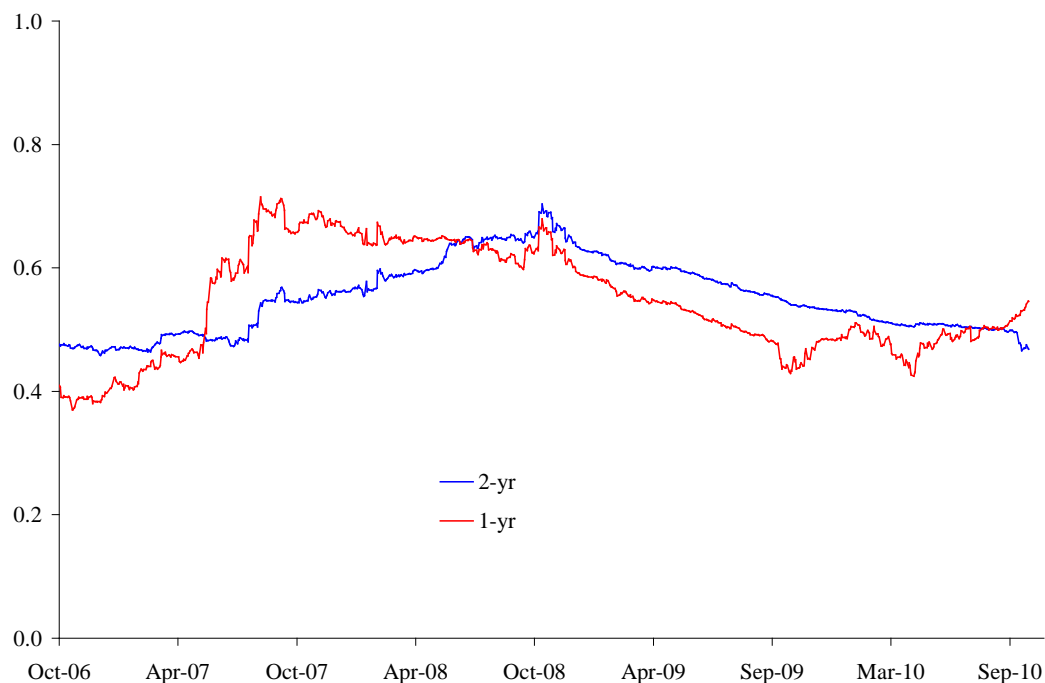**Figure 9: Two-year asset betas - FTSE All-Share**

**Figure 10: One and two year asset betas – BT vs FTSE All-Share**



Because of the substantial variation in BT's financial leverage during the last several years, we perform further calculations to assess the robustness of our standard calculations. Large swings in leverage reduce the accuracy of the standard calculations because they presume that the target parameter – equity beta – remains broadly stable throughout the measurement window. However, at least in theory, large variations in financial leverage should prompt shifts in the equity beta over time.

We estimate BT's asset beta directly, by constructing "unlevered returns" from holding a combined portfolio of BT's equity and debt. We design the portfolio specifically to mimic BT as a whole. The "unlevered returns" represent the weighted average returns on BT's publicly traded debt and equity, with the weights reflecting relative shares of BT's debt and equity. The weights depend on market values. We calculate the returns to debt based on the available market data for BT's outstanding debt, and the returns to equity in the standard way with reference to stock prices. For comparison, we also report the asset betas implied by taking our raw equity betas and relevering them using the standard formula and assuming a 0.15 debt beta. The direct approach gives a lower result to the standard formula (0.33 vs 0.47 as of October 2010). The difference remains within two standard deviations, but raises concerns about our ability to obtain accurate estimates while BT's leverage swings dramatically.

**Figure 11: Direct asset beta**
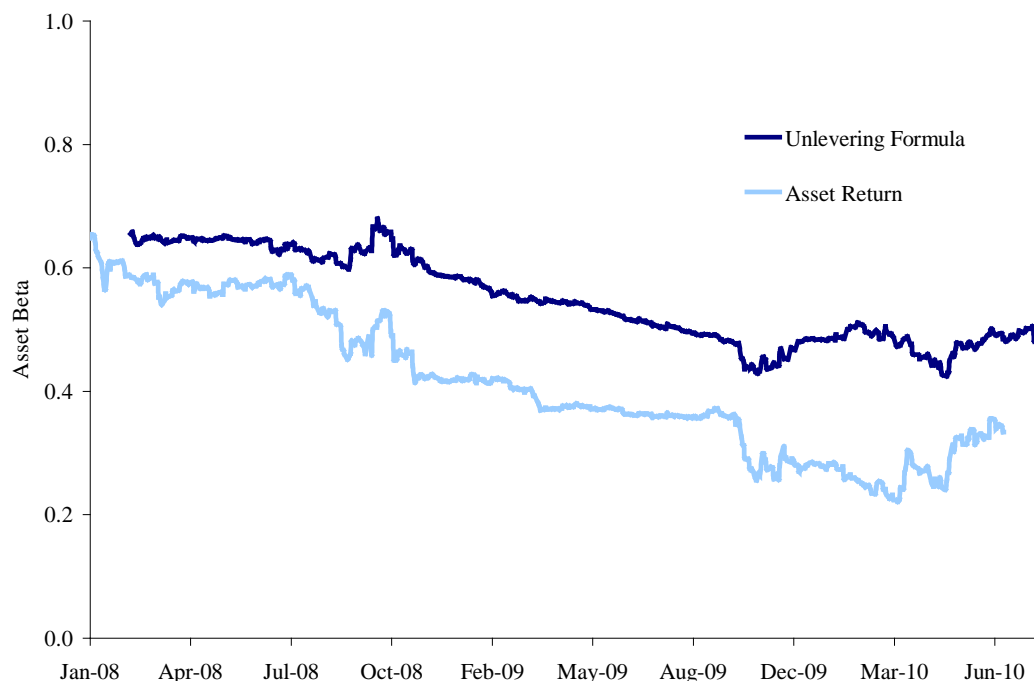


## 2.3 US Telecoms

In addition to the UK utility reference sample, we examined data for eleven US telecommunications companies. The companies are engaged in both wireline and wireless activities. Three of the companies were pure-play wireline (Frontier, Qwest and Windstream), meaning that the core business of these companies involved local loop access and the provision of associated telephone services such as local telephone calls and retail broadband. Wireline activities accounted for half the revenues of two other of the US companies (AT&T and Verizon), while the remaining six companies are engaged predominately in the provision of wireless services, such as mobile phones and broadband. Data for the US telecoms companies is relevant for our purpose to the extent that it reflects businesses whose principal activities is access to the local loop.

Using the standard techniques, we estimated asset betas for all of the US telecoms companies. Figure 12 to Figure 13 plot the development of the asset beta for the three pure-play wireline stocks. Although the wireline companies provide retail broadband and local telephone services, a substantial portion of the revenues for all companies stem from the provision of access to the local loop. Asset betas for the wireline stocks against the S&P 500 come in just slightly below the level for BT against the FTSE All-Share. The one-year betas for the three wireline stocks display a slight reduction more recently, but not to the same level as we observe for the UK utilities other than BT.

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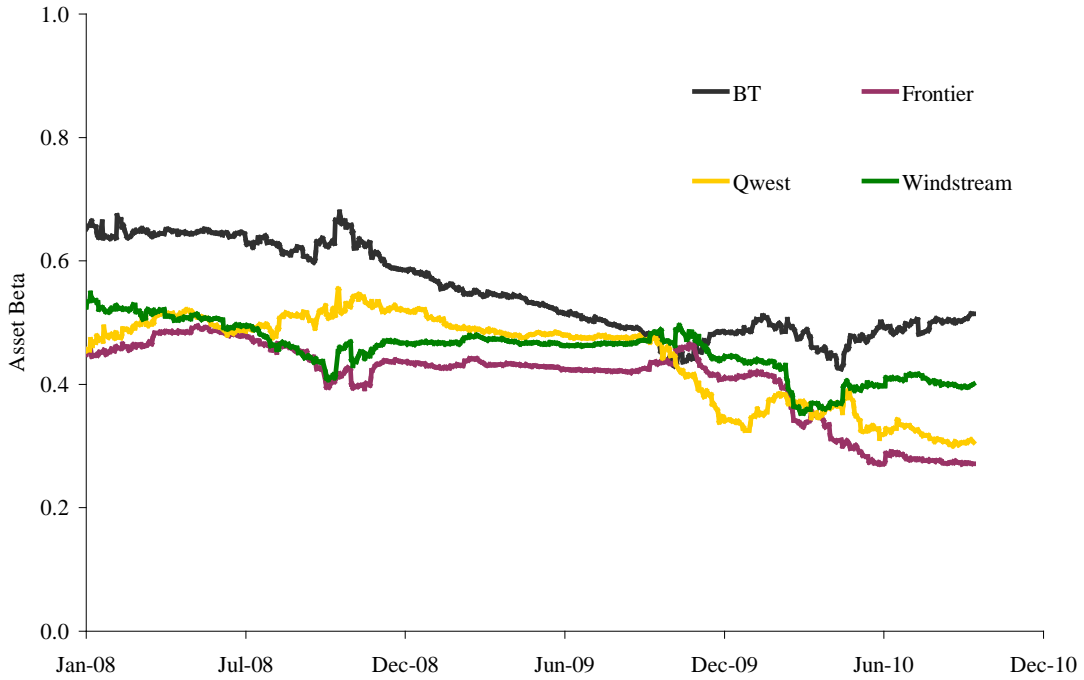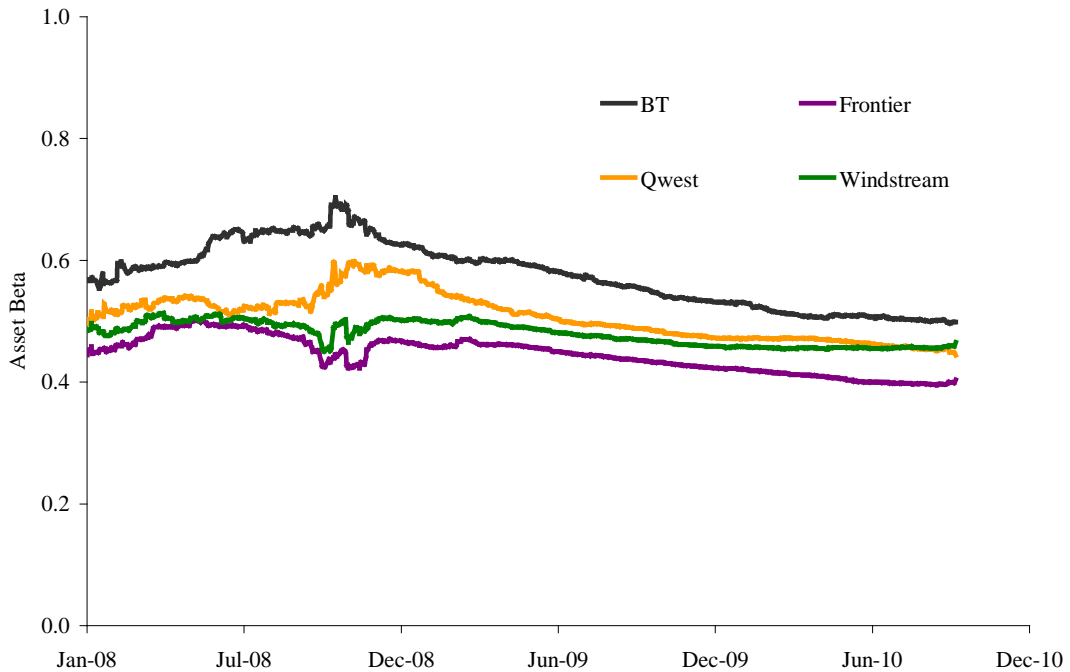**Figure 12: One-year asset betas - Wireline**



**Figure 13: Two-year asset betas – Wireline**



We use the broader sample of US telecom stocks to test whether the beta for wireline activities is much different from that for wireless. Figure 14 organises the latest two year beta estimates for the US companies according to the percentage of revenues coming from different activities. The pure-play wireline stocks appear on the left hand side of the graph, while pure-play wireless appear on the right-hand side. Diversified telecoms companies such as AT&T appear somewhere in the middle. There is no obvious trend

from left-to-right for either the one-year or two-year beta estimates, indicating a similar level of beta for wireline and wireless activities. The average asset beta for the broad sample of US telecoms companies comes in close to that for BT (for one-year 0.48 vs 0.55; for two-year 0.54 vs 0.47). The US data provides support for the reliability of our up-to-date estimate for BT.

**Figure 14: Two-year betas**
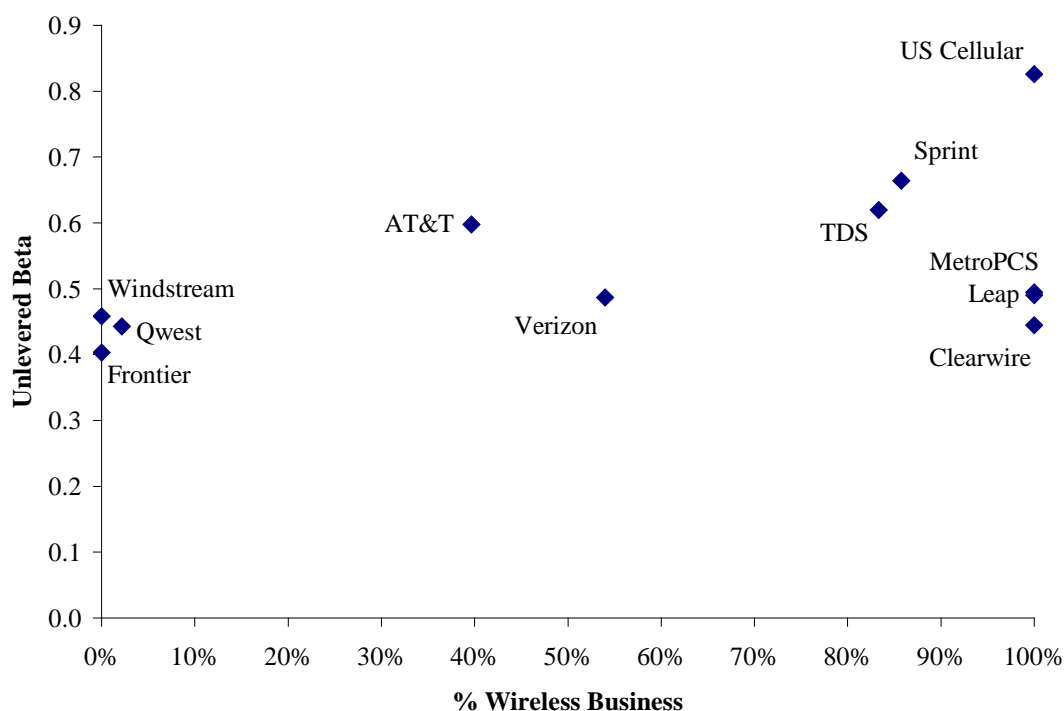


## 2.4 Conclusions

We remain concerned about the large swing in BT's financial leverage over the past two-years and its implications for our beta calculations. Since October 2008, BT's financial leverage has more than doubled as a result of a large drop in BT's share price, before falling back somewhat following a rebound in BT's share price. Large swings in financial leverage introduce additional uncertainty to our beta estimates over and above that due to the normal level of variation in the underlying data.

Based on our regressions, the last two years of data generates an estimate for the equity beta of BT is 0.84 against the FTSE All-Share. This estimate corresponds with average leverage during the two-year measurement window of 53%, and implies an asset beta for BT of just under 0.47. The last year of data generates slightly higher estimates: an equity beta of 0.96 against the FTSE All-Share, corresponding with average leverage of just over 50%. The last year of data implies an asset beta of 0.55. Based on the latest data available, there is no evidence of a significant change in the level of BT's beta since our last update.

What is clear is that BT's one-year beta has not followed the same trend as those for other UK utility companies since 2008. The other UK utilities evidence a step decrease in equity beta, following the elimination of pre-crisis data from the analysis, while BT's beta displays no such drop. If we attribute recent movements in the betas to the credit crisis,

then investors appear to have distinguished between BT, National Grid and the water companies. Investors apparently considered National Grid and the water companies to represent "safe havens" during the crisis, but to have considered BT more risky perhaps because of uncertainty over the pension fund deficit or the poor performance of some of BT's non-core business.

We also observe no significant decline in the betas of US telecoms companies since 2008. The most recent beta estimates for US telecoms companies remain above those observed for the UK energy and water utilties, and resemble those for BT. Analysis of the US stock market data reveals no significant difference between the betas for telecoms companies focussing on wireline activities and those focusing on wireless.

We would normally recommend a range of +/- approximately two standard deviations around our mid-point figures (0.96 for the last year of data, and 0.84 for the last two-years). However, we hesitate to report a range in this case because of our concern about the impact of the swing in BT's financial leverage over the past two years.

# 3  Statistical reliability

The use of daily returns data in regressions to estimate equity beta can risk introducing statistical problems, for example in relation to thin trading. We discussed these problems in earlier papers for Ofcom.[8] We perform a number of statistical tests to check for potential problems in this case.

## 3.1 Dimson adjustment

To test for possible bias relating to trading illiquidity and to assess if time differences[9] caused distortions, we perform the "Dimson" adjustment to the estimated betas by including a one period lag and a one period lead. For BT and the five other UK utilities, the separate lead and lag terms are seldom significantly different from zero and the Dimson adjustment overall was significantly different from zero in only one case out of a total of 24 different beta estimates. Nevertheless, we note that the Dimson adjustments appear to increase the latest one-year estimates for BT by a substantial amount (0.96 against the All-Share rises to 1.12 when we add one-day lead and lag terms). Although the rise in beta is close to 0.2, it turns out to be statistically insignificant because of a matching rise in the level of uncertainty. The statistical uncertainty associated with the BT estimates is itself higher than for the other UK utilities. Table 3 reports Dimson betas for the UK utilities.

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[8] See *Issues in beta estimation for UK mobile operators*, July 2002.

[9] The London Stock Exchange closes at 5pm BST, while the markets in other countries may close earlier or later. Broad index data may therefore combine closing prices relating to different time of day.

**Table 3: Dimson adjustments – up-to-date data**

| | 1 Yr | | | | 2 Yr | | | |
|---|---|---|---|---|---|---|---|---|
| | Beta | Dimson Beta | Dimson SE | Significance | Beta | Dimson Beta | Dimson SE | Significance |
| *BT* | | | | | | | | |
| All World | 0.86 | 1.23 | 0.25 | Neither lag nor lead | 0.67 | 0.74 | 0.17 | Neither lag nor lead |
| All Share | 0.96 | 1.12 | 0.20 | Only lag | 0.84 | 0.87 | 0.15 | Neither lag nor lead |
| ***UK Utility Peer Group*** | | | | | | | | |
| *National Grid* | | | | | | | | |
| All World | 0.53 | 0.65 | 0.14 | Neither lag nor lead | 0.40 | 0.68 | 0.11 | Only lead |
| All Share | 0.52 | 0.62 | 0.12 | Neither lag nor lead | 0.62 | 0.64 | 0.09 | Neither lag nor lead |
| *Northumbrian Water* | | | | | | | | |
| All World | 0.45 | 0.36 | 0.16 | Neither lag nor lead | 0.34 | 0.32 | 0.11 | Neither lag nor lead |
| All Share | 0.46 | 0.49 | 0.15 | Neither lag nor lead | 0.53 | 0.51 | 0.10 | Neither lag nor lead |
| *Pennon Group* | | | | | | | | |
| All World | 0.45 | 0.50 | 0.15 | Neither lag nor lead | 0.42 | 0.46 | 0.12 | Neither lag nor lead |
| All Share | 0.47 | 0.60 | 0.13 | Neither lag nor lead | 0.60 | 0.64 | 0.10 | Only lag |
| *Severn Trent* | | | | | | | | |
| All World | 0.42 | 0.39 | 0.14 | Neither lag nor lead | 0.39 | 0.41 | 0.11 | Neither lag nor lead |
| All Share | 0.38 | 0.50 | 0.12 | Neither lag nor lead | 0.53 | 0.52 | 0.10 | Neither lag nor lead |
| *United Utilities* | | | | | | | | |
| All World | 0.42 | 0.34 | 0.14 | Neither lag nor lead | 0.40 | 0.45 | 0.10 | Neither lag nor lead |
| All Share | 0.40 | 0.39 | 0.12 | Neither lag nor lead | 0.54 | 0.49 | 0.08 | Neither lag nor lead |

## 3.2 Tests for heteroscedasticity and auto-correlation

We perform a series of standard diagnostic tests to assess if the beta estimates satisfy the standard conditions underlying ordinary least squares regression. The standard conditions are that the error terms in the regression follow a normal distribution and that they do not suffer from heteroscedasticity (linked to the fitted values) or auto-correlation (follow some pattern over time). Failure to meet these conditions would not invalidate the beta estimates, but would have the following consequences:

1. Although OLS is still an unbiased procedure in the presence of heteroscedasticity and/or autocorrelation, it is no longer the best or least variance estimator.

2. In the presence of heteroscedasticity and/or autocorrelation, the standard error calculated in the normal way may understate the true uncertainty of the beta estimate.

3. Heteroscedasticity and/or auto-correlation may indicate that the underlying regression is mis-specified (i.e. we have left out some explanatory variable).

4. Failure of normality does not *per se* undermine the validity of OLS, but the presence of outliers raises difficult questions about the robustness of the beta estimates.

### *Heteroscedasticity*

Figure 15 to Figure 20 show scatter plots of the residuals against the returns predicted by the regression, for two-year regressions against the FTSE All-World. We constructed comparable plots for our regressions against the other indices and for our shorter one year beta estimates. Visual inspection does not reveal any obvious pattern - the "vertical spread" does not appear to change in any systematic way as we move horizontally across the graph. However, there are clearly a number of outliers.

**Figure 15: BT - residuals against fitted values**
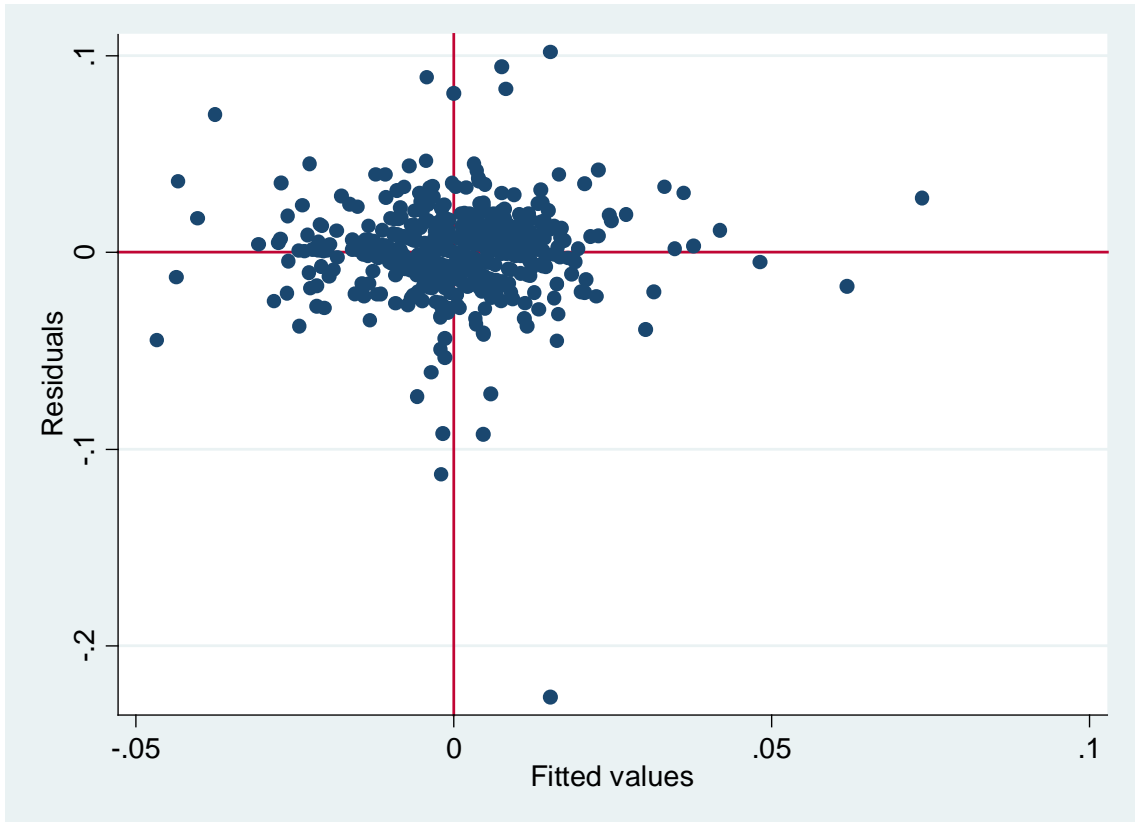


**Figure 16: National Grid - residuals against fitted values**
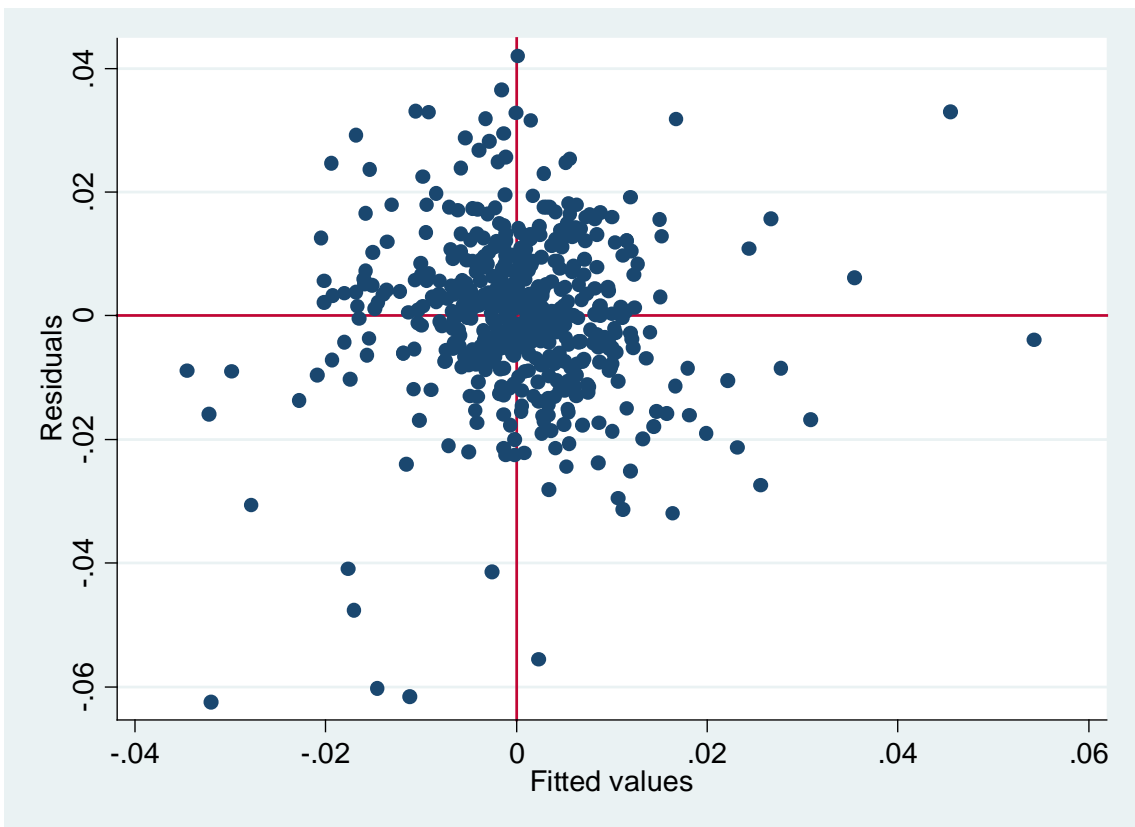
**Figure 17: Northumbrian Water – residuals against fitted values**
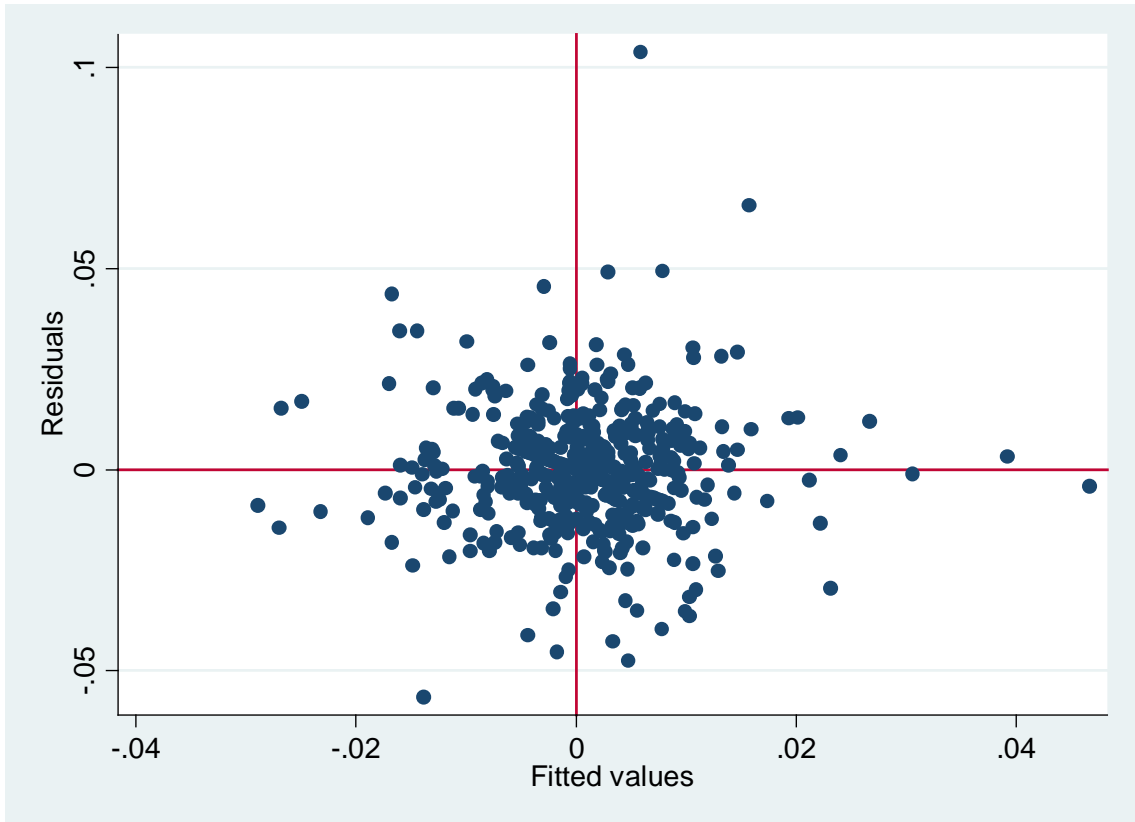


**Figure 18: Pennon Group – residuals against fitted values**
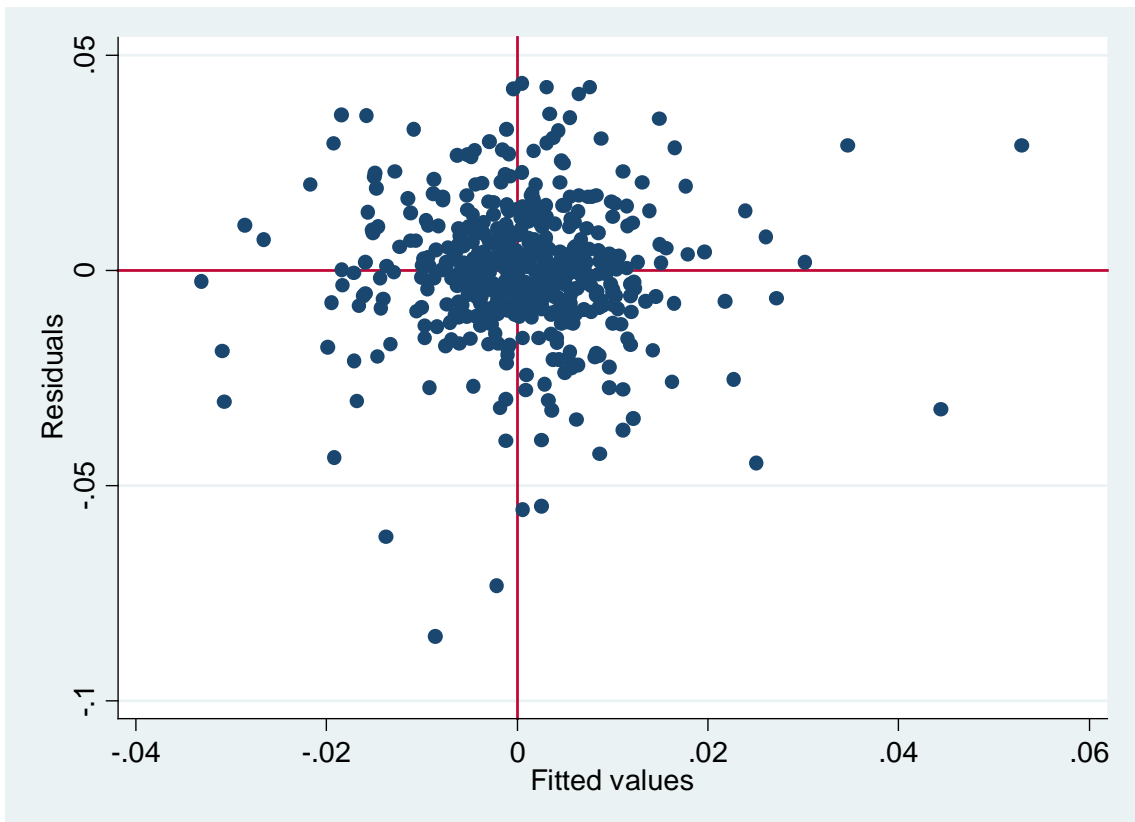
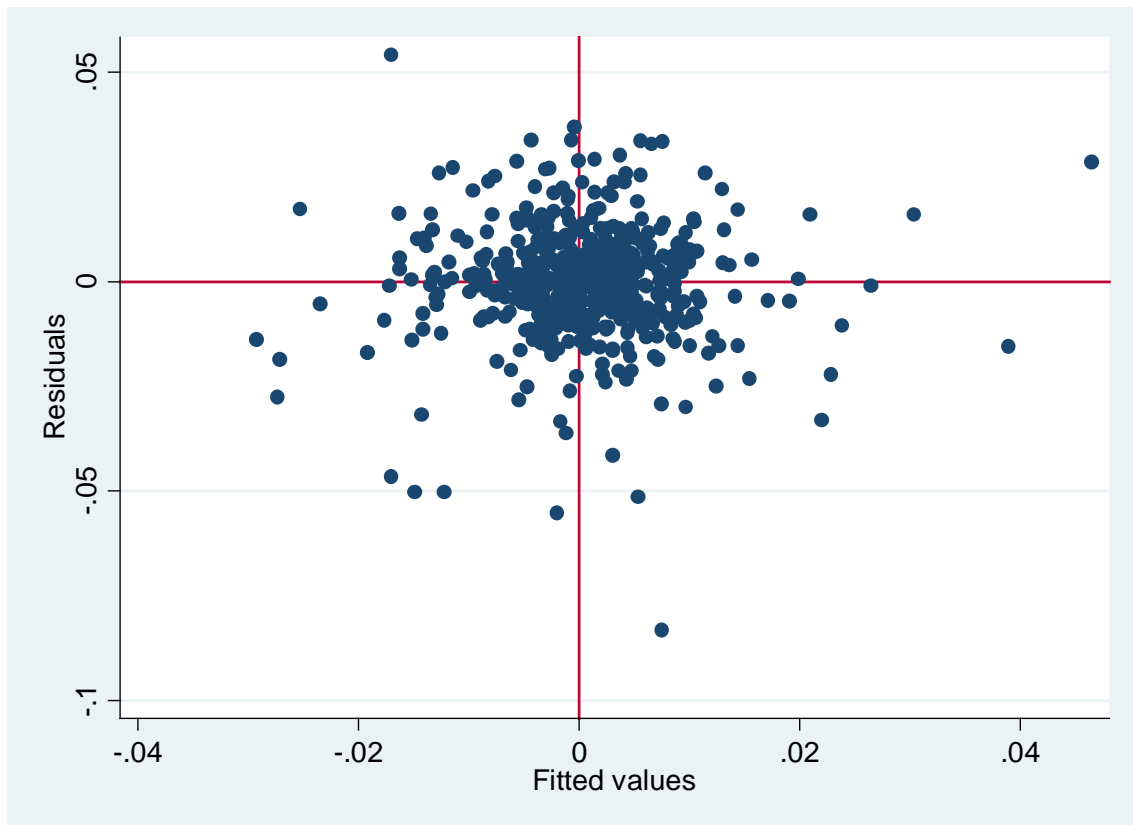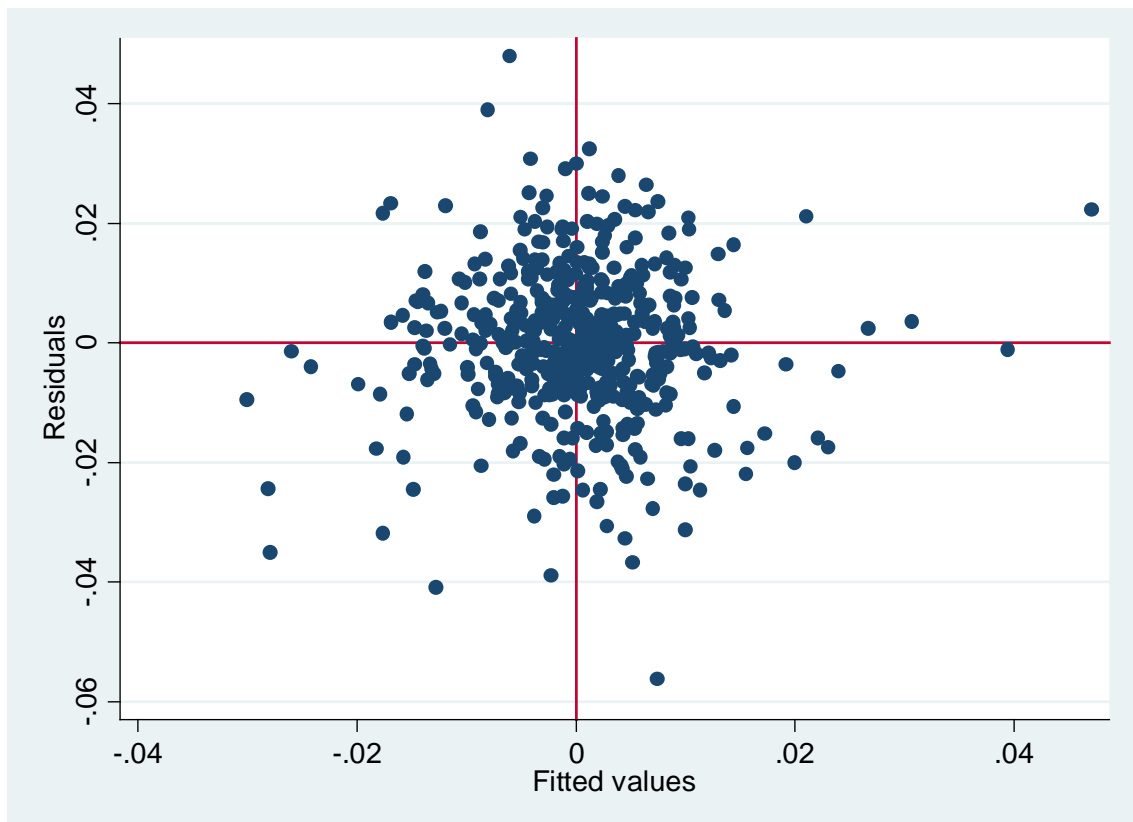**Figure 19: Severn Trent – residuals against fitted values**



**Figure 20: United Utilities – residuals against fitted values**



We also examine whether there is change in the pattern of residuals over time. Figure 21 to Figure 26 show an apparent decline in the magnitude of the residuals since the end

of 2008. All this appears to reflect market turmoil, and the extreme volatility witnessed during the heart of the credit crisis, as well as some recovery since then. The plots again relate to two-year beta estimates calculated against the FTSE All-World.
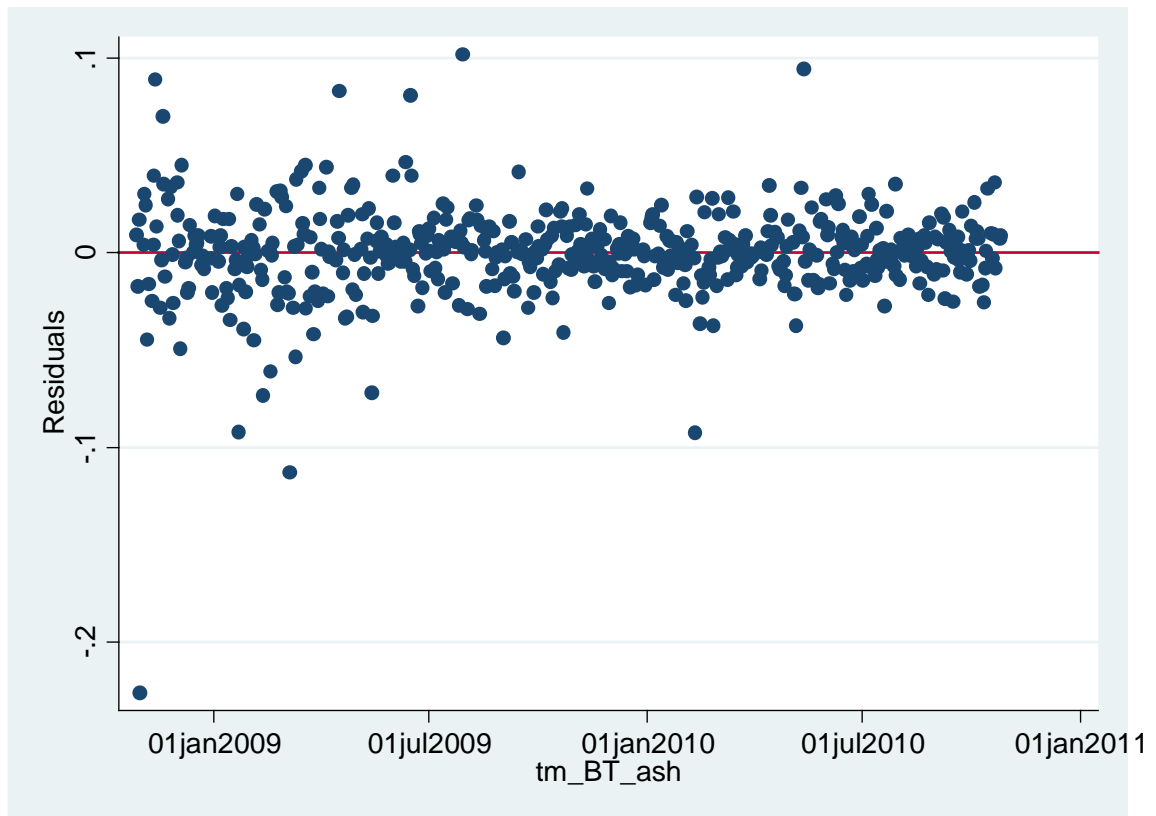
**Figure 21: BT - residuals over time**
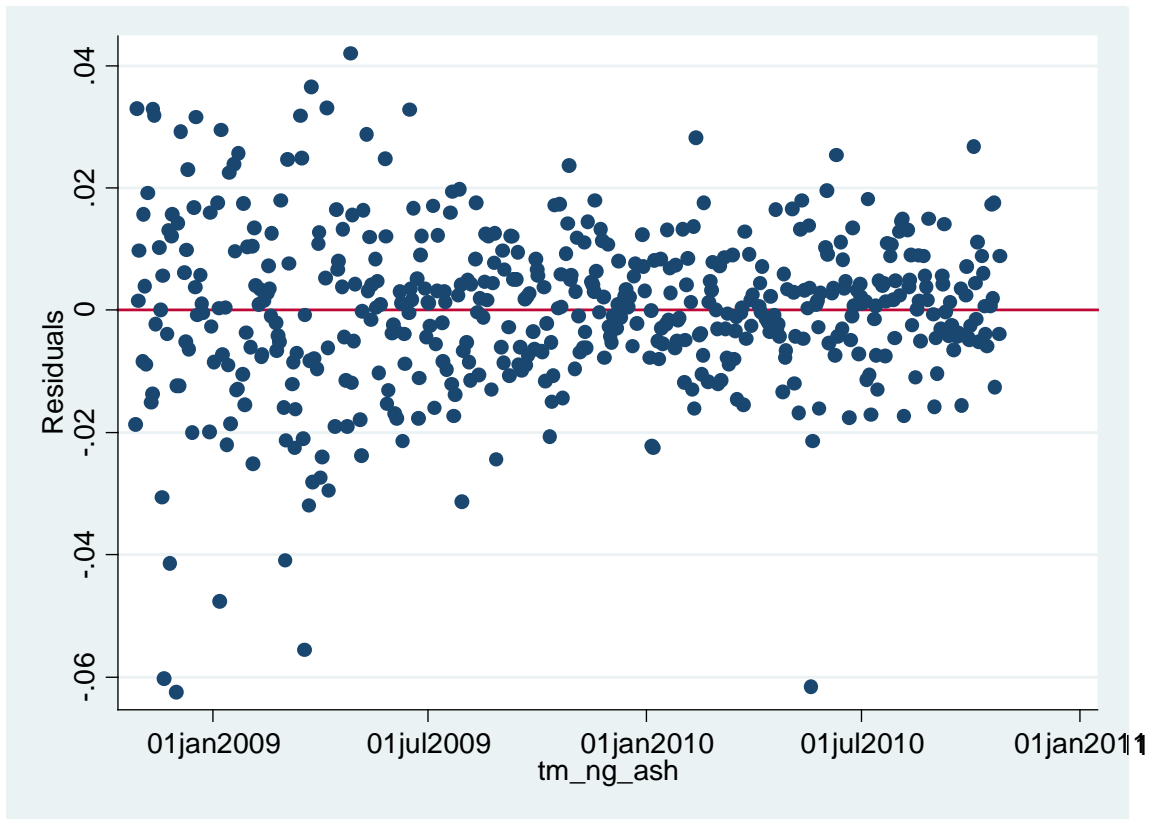
**Figure 22: National Grid – residuals over time**



**Figure 23: Northumbrian Water – residuals over time**
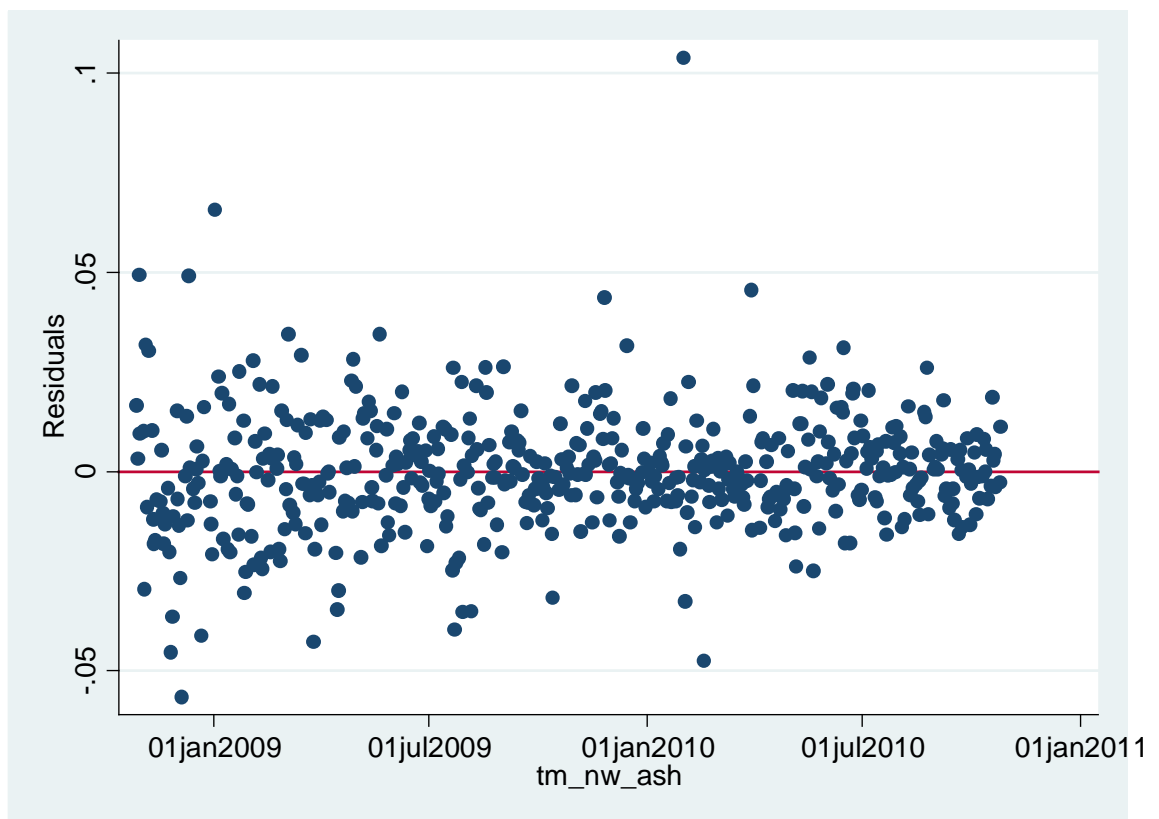
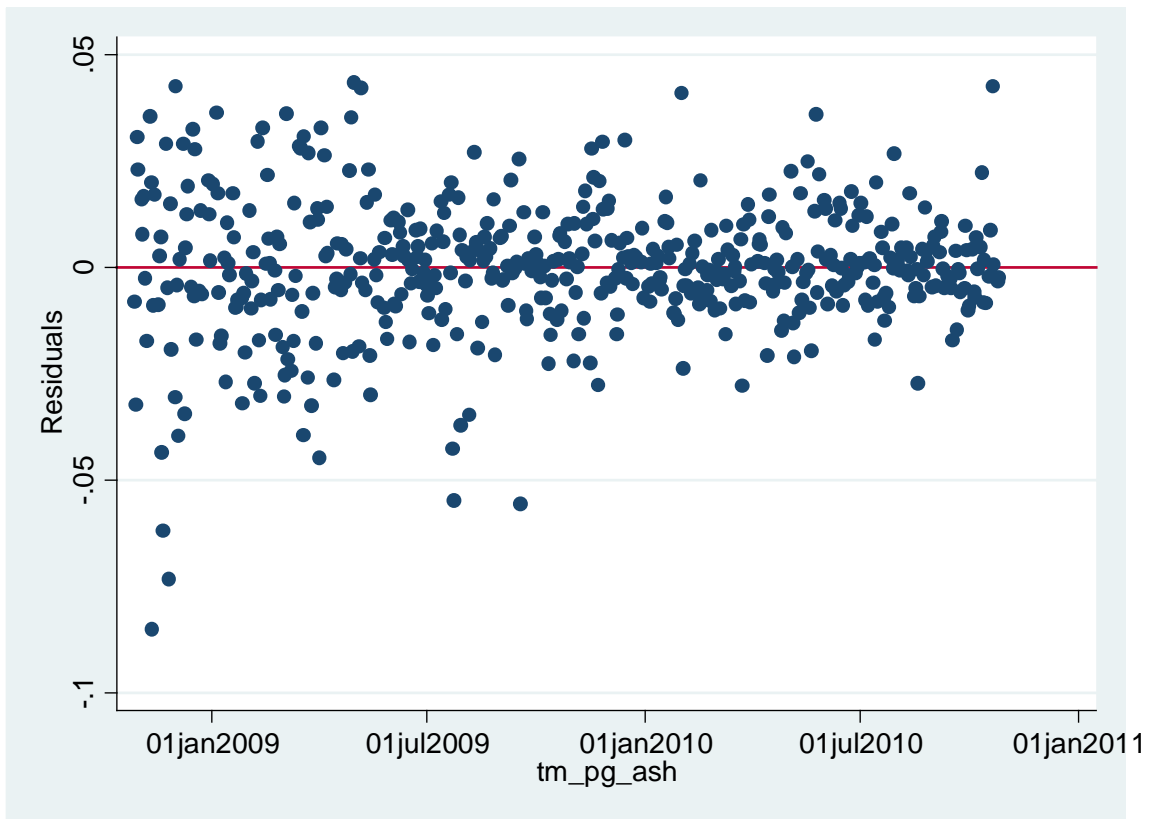**Figure 24: Pennon Group – residuals over time**



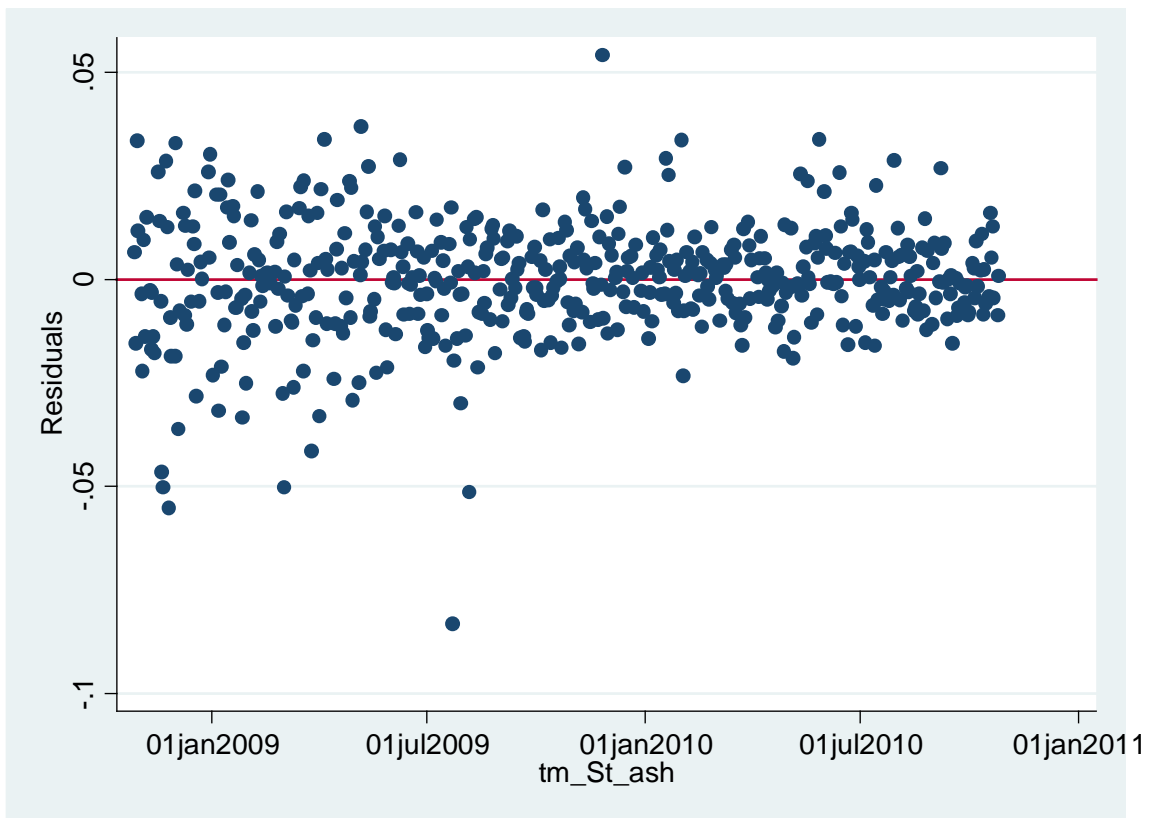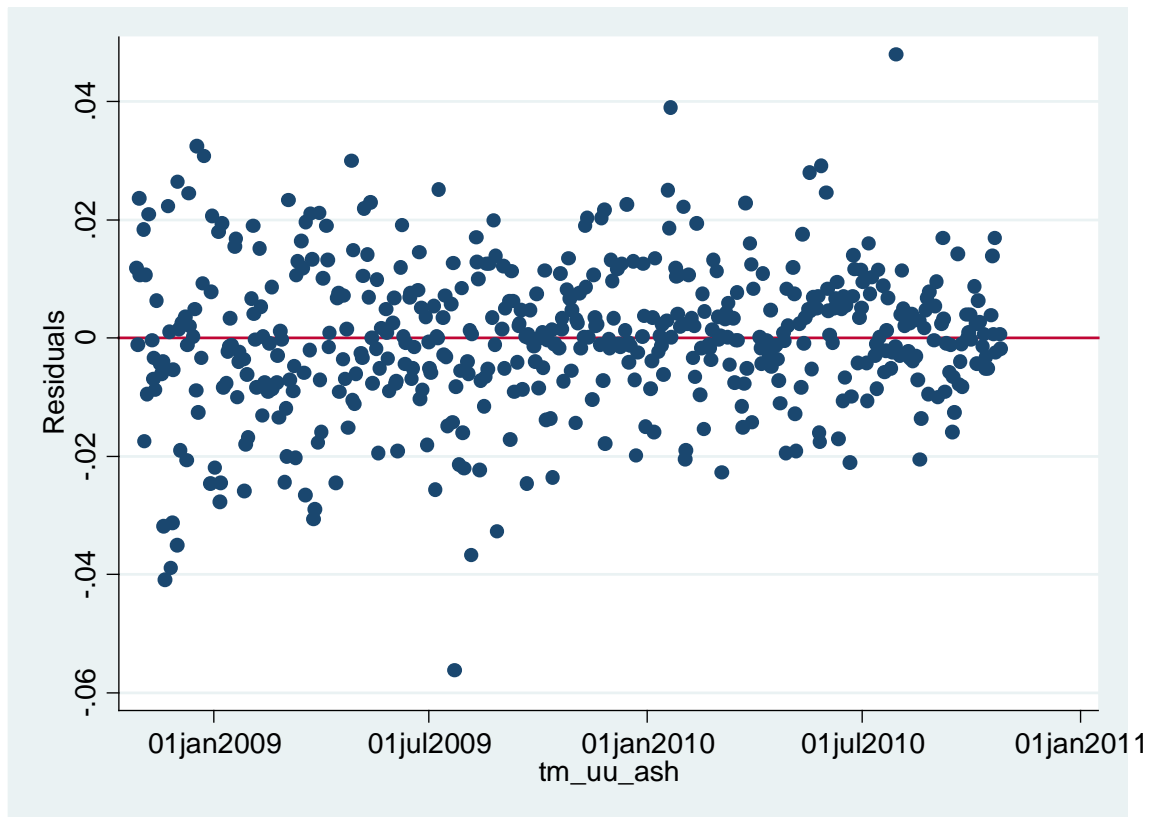**Figure 25: Severn Trent – residuals over time**

**Figure 26: United Utilities – residuals over time**



Since simple inspection suggests that there may be some heteroscedasticity, we apply a formal test (White's test) to investigate further. Table 4 report results.

**Table 4: Cameron & Trivedi's test for heteroscedasticity – up-to-date data**

| | 1 yr | | | 2 yr | | |
|---|---|---|---|---|---|---|
| | White Stat | p-value | Heterosk-edascity | White Stat | p-value | Heterosk-edascity |
| *BT* | | | | | | |
| All World | 0.43 | 0.81 | No | 4.07 | 0.13 | No |
| All Share | 0.70 | 0.71 | No | 1.05 | 0.59 | No |
| ***UK Utility Peer Group*** | | | | | | |
| *National Grid* | | | | | | |
| All World | 16.91 | 0.00 | Yes | 34.52 | 0.00 | Yes |
| All Share | 1.32 | 0.52 | No | 25.61 | 0.00 | Yes |
| *Northumbrian Water* | | | | | | |
| All World | 1.19 | 0.55 | No | 7.93 | 0.02 | Yes |
| All Share | 0.51 | 0.78 | No | 0.75 | 0.69 | No |
| *Pennon Group* | | | | | | |
| All World | 0.58 | 0.75 | No | 21.94 | 0.00 | Yes |
| All Share | 3.60 | 0.17 | No | 6.95 | 0.03 | Yes |
| *Severn Trent* | | | | | | |
| All World | 1.06 | 0.59 | No | 18.16 | 0.00 | Yes |
| All Share | 8.19 | 0.02 | Yes | 7.61 | 0.02 | Yes |
| *United Utilities* | | | | | | |
| All World | 1.89 | 0.39 | No | 17.26 | 0.00 | Yes |
| All Share | 0.67 | 0.72 | No | 3.77 | 0.15 | No |

The tables indicate the presence of some heteroscedascity in the two year estimates, but less problems in the one-year estimates. This most likely relates to the significant increase in market volatility around the heart of the crisis, and a subsequent decrease.

### *Auto-correlation*

We also perform a formal test for auto-correlation (the Durbin-Watson test). Unsurprisingly, this test indicates a degree of autocorrelation in all of the regressions, also likely reflecting the development of the credit crisis and the changing extent of market volatility. The effect of this auto-correlation is that standard errors will over-estimate the precision of the regression.

**Table 5: Durbin–Watson test for autocorrelation – up-to-date data**

| | 1 yr | | 2 yr | |
|---|---|---|---|---|
| | DW Stat | Serial Correlation | DW Stat | Serial Correlation |
| *BT* | | | | |
| All World | 1.764 | Indecisive | 1.528 | Yes |
| All Share | 1.728 | Yes | 1.537 | Yes |
| ***UK Utility Peer Group*** | | | | |
| *National Grid* | | | | |
| All World | 1.479 | Yes | 1.653 | Yes |
| All Share | 1.547 | Yes | 1.617 | Yes |
| *Northumbrian Water* | | | | |
| All World | 1.590 | Yes | 1.550 | Yes |
| All Share | 1.649 | Yes | 1.590 | Yes |
| *Pennon Group* | | | | |
| All World | 1.606 | Yes | 1.576 | Yes |
| All Share | 1.713 | Yes | 1.726 | Yes |
| *Severn Trent* | | | | |
| All World | 1.631 | Yes | 1.539 | Yes |
| All Share | 1.760 | Indecisive | 1.654 | Yes |
| *United Utilities* | | | | |
| All World | 1.454 | Yes | 1.554 | Yes |
| All Share | 1.502 | Yes | 1.564 | Yes |

### *Robust regresssion*

We performed a robust regression that accommodates the presence of some heteroscedascity in the data. The robust regression is a standard feature of computerised statistical packages like STATA. The robust regression derives the same coefficients as standard OLS, but calculates standard errors robust to heteroscedascity. We find that the robust standard errors are close to the OLS ones (see Table 6). The presence of auto-correlation should not affect the central beta estimates, but means that even the robust standard errors will underestimate the true level of uncertainty associated with the measurements.

**Table 6: Robust standard errors – up-to-date data**

|  | 1 yr | | | 2 yr | | |
|---|---|---|---|---|---|---|
|  | Beta | SE | Robust SE | Beta | SE | Robust SE |
| *BT* |  |  |  |  |  |  |
| All World | 0.86 | 0.12 | 0.13 | 0.67 | 0.08 | 0.11 |
| All Share | 0.96 | 0.09 | 0.08 | 0.84 | 0.07 | 0.08 |
| ***UK Utility Peer Group*** |  |  |  |  |  |  |
| *National Grid* |  |  |  |  |  |  |
| All World | 0.53 | 0.07 | 0.10 | 0.40 | 0.05 | 0.08 |
| All Share | 0.52 | 0.05 | 0.06 | 0.62 | 0.04 | 0.06 |
| *Northumbrian Water* |  |  |  |  |  |  |
| All World | 0.45 | 0.09 | 0.10 | 0.34 | 0.05 | 0.07 |
| All Share | 0.46 | 0.07 | 0.08 | 0.53 | 0.04 | 0.05 |
| *Pennon Group* |  |  |  |  |  |  |
| All World | 0.45 | 0.08 | 0.08 | 0.42 | 0.06 | 0.08 |
| All Share | 0.47 | 0.06 | 0.07 | 0.60 | 0.05 | 0.06 |
| *Severn Trent* |  |  |  |  |  |  |
| All World | 0.42 | 0.07 | 0.07 | 0.39 | 0.05 | 0.07 |
| All Share | 0.38 | 0.06 | 0.07 | 0.53 | 0.04 | 0.05 |
| *United Utilities* |  |  |  |  |  |  |
| All World | 0.42 | 0.07 | 0.07 | 0.40 | 0.04 | 0.06 |
| All Share | 0.40 | 0.06 | 0.06 | 0.54 | 0.04 | 0.04 |

## 3.3 Normality of residuals

We plot histograms of the "studentised residuals" to test for the normality of the residuals. The curve superimposed on the histograms is a standard normal distribution. If the error terms follow a normal distribution then the studentised residuals should follow the t-distribution, which for our size of sample is practically indistinguishable from the standard normal distribution. The histograms broadly resemble normal distributions except for the outliers: there are a few too many points a large number of standard deviations away from zero. Figure 27 to Figure 32 show histograms for two-year FTSE All-World regressions.
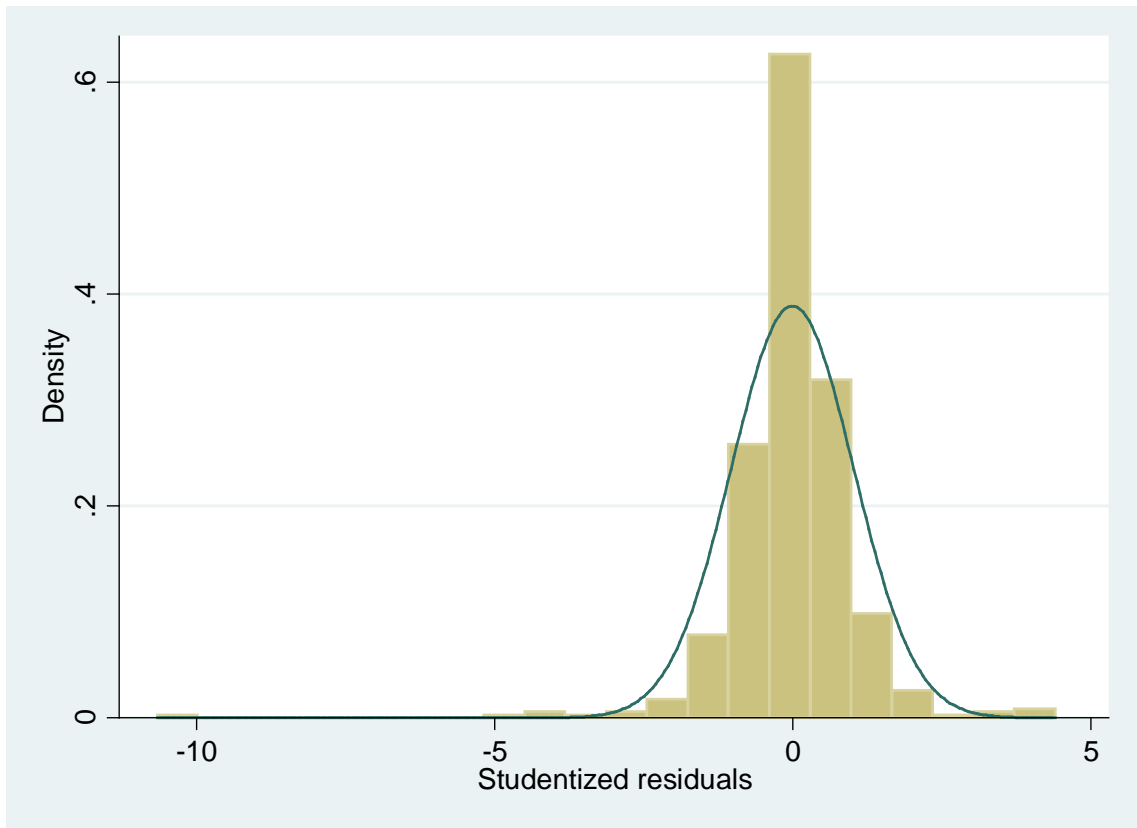
**Figure 27: Studentized residuals - BT**



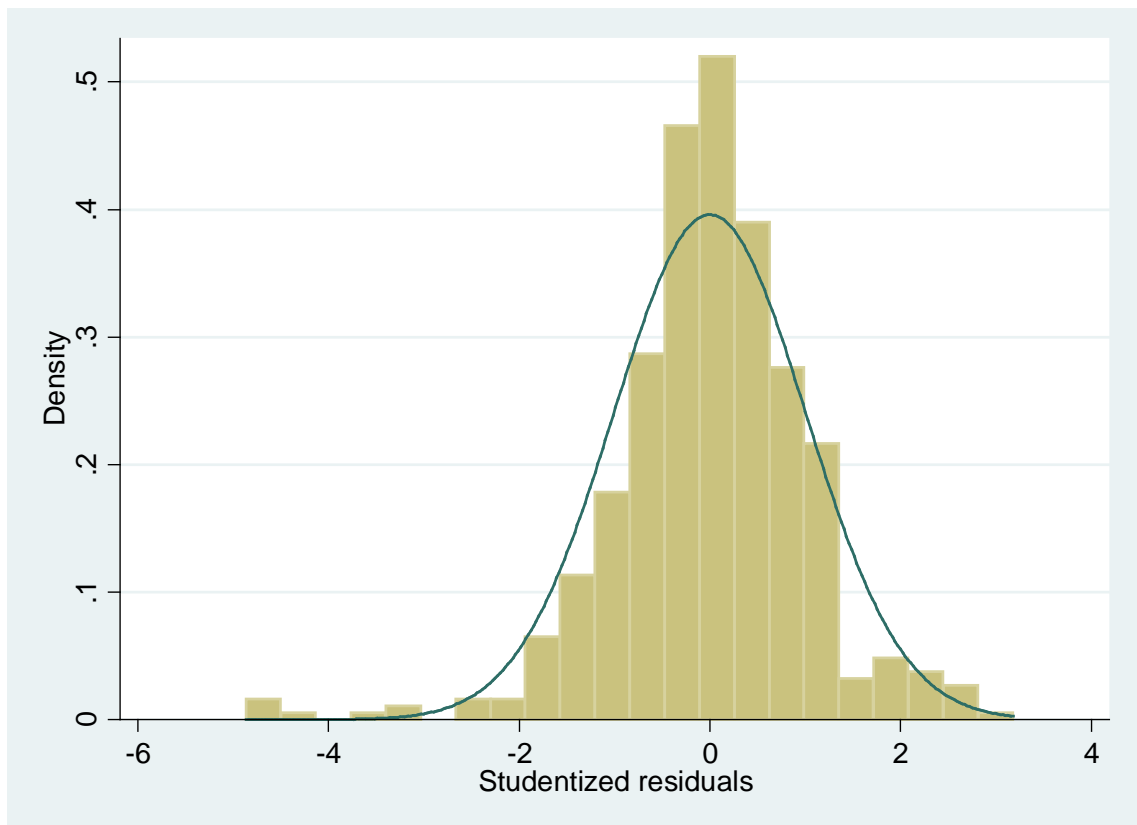**Figure 28: Studentized residuals – National Grid**

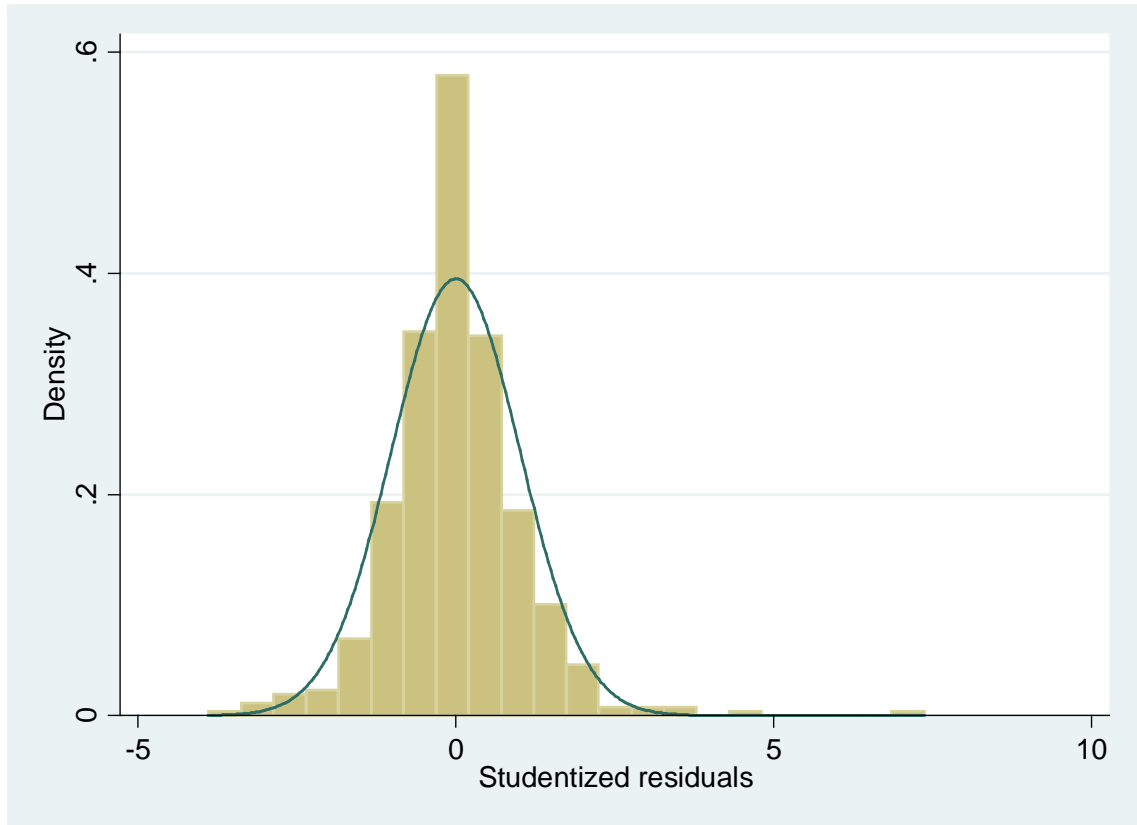**Figure 29: Studentized residuals - Northumbrian Water**



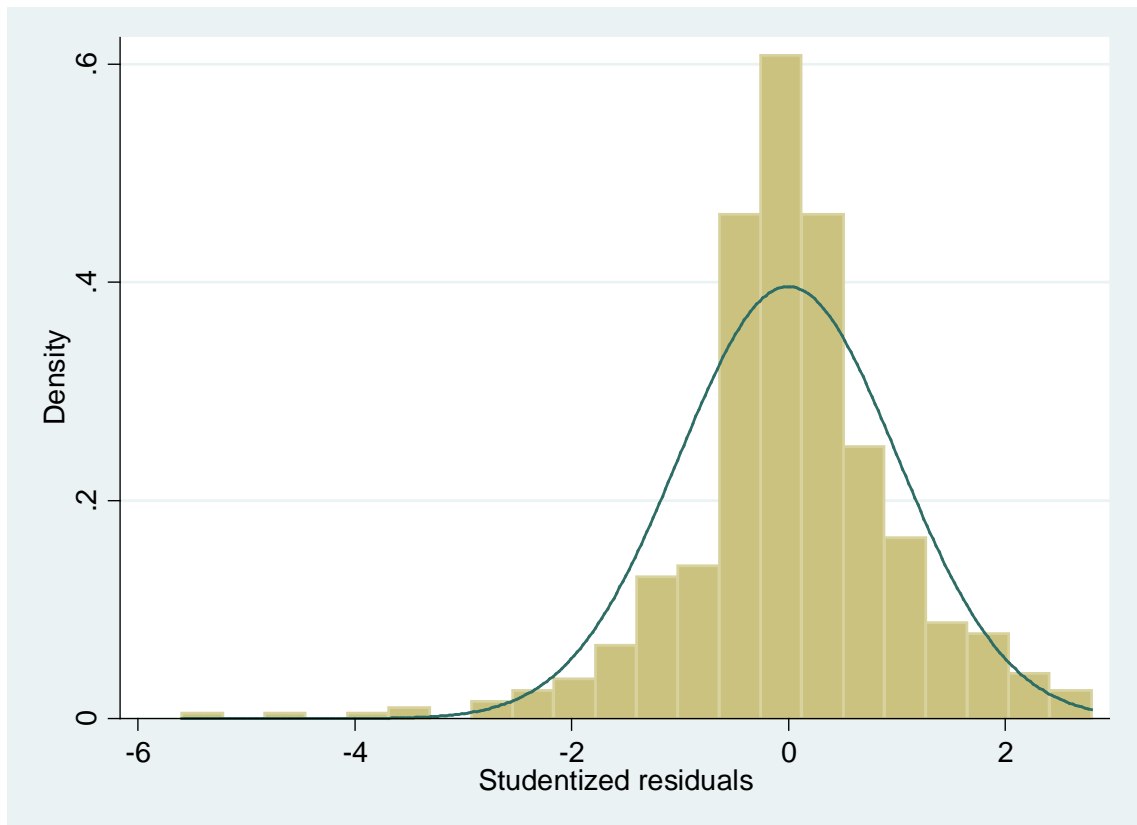**Figure 30: Studentized residuals – Pennon Group**

**Figure 31: Studentized residuals – Severn Trent**
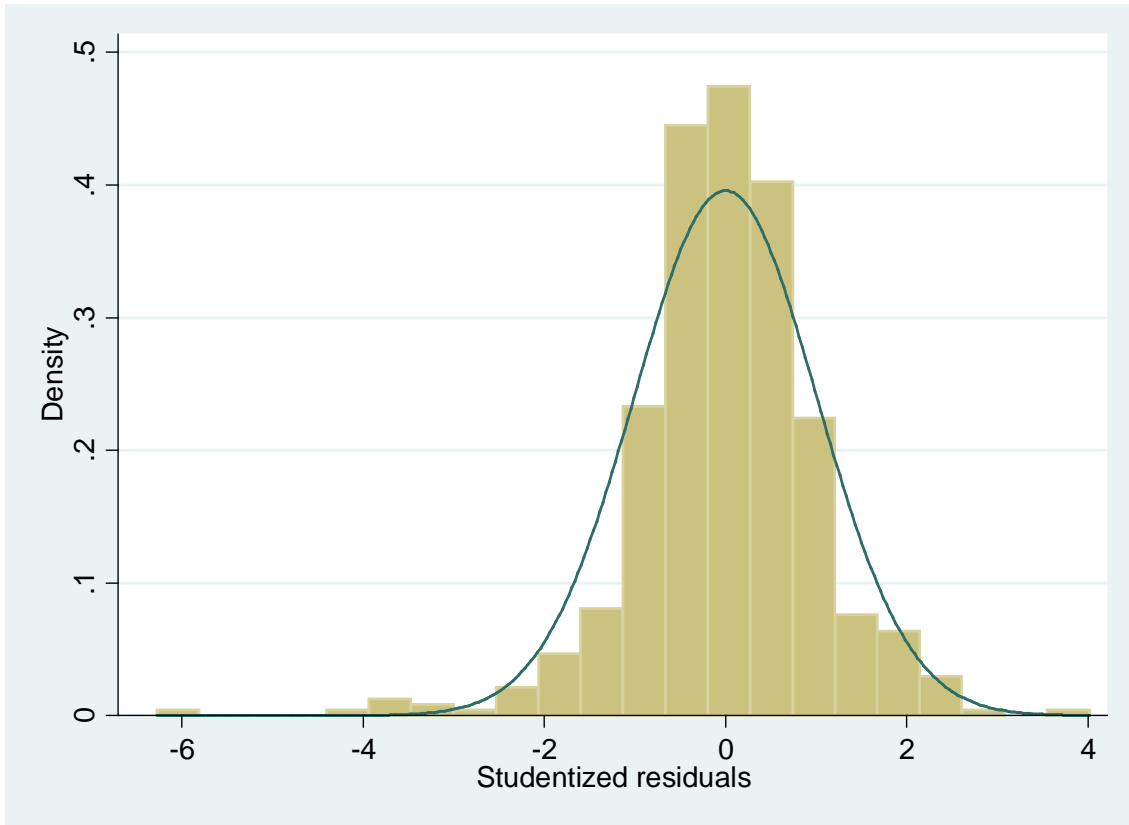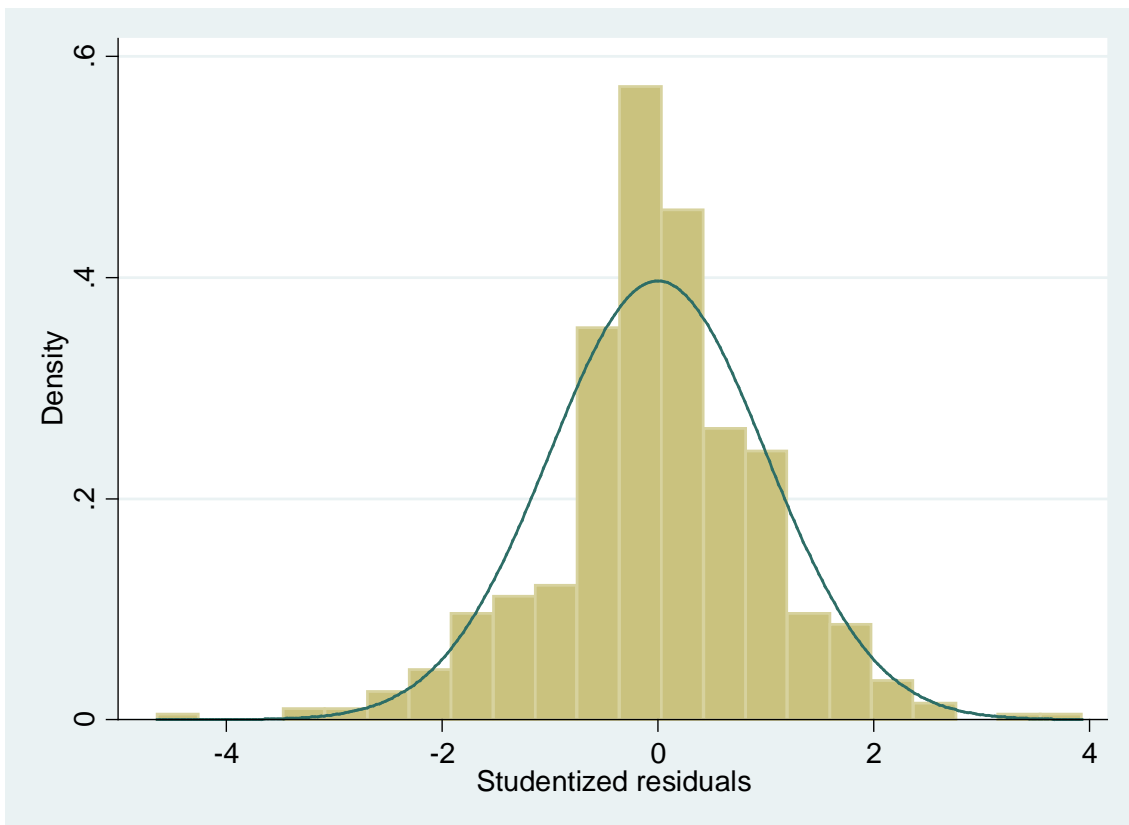


**Figure 32: Studentized residuals – United Utilities**

### 3.4 Outliers

We perform two analyses to understand the influence of particular points on our beta estimates. We repeat the standard OLS regressions but only after removing "influential outliers". We also perform an iterative regression that gives less weight to data points reporting large residuals and enjoying high leverage (i.e. influence on the regression line).

To identify potential outliers we calculate the 'Cook's D' measure of the influence of each point on the regression outcome. A usual threshold is to classify points with a Cook's D score over 4/N (number of observations) as influential. Table 7 lists such influential dates for the two year betas calculated using up-to-date data. More than half of the influential "outliers" occurred during September to December 2008 – i.e. in the immediate aftermath of the collapse of Lehman Brothers. No other period of the data window contributes as many outliers.

**Table 7: influential outliers, two-year regressions**

| BT | | | |
|---|---|---|---|
| **All World** | | **All Share** | |
| 1 Yr | 2 Yr | 1 Yr | 2 Yr |
| 12-Nov-09 | 02-Mar-09 | 07-May-10 | 26-Jan-09 |
| 01-Mar-10 | 24-Feb-09 | 11-Feb-10 | 13-May-10 |
| 01-Jun-10 | 23-Feb-09 | 26-Feb-10 | 17-Apr-09 |
| 10-May-10 | 06-Nov-08 | 13-May-10 | 30-Jul-09 |
| 20-May-10 | 30-Mar-09 | 20-May-10 | 20-Nov-08 |
| 11-May-10 | 10-May-10 | 29-Jun-10 | 04-Nov-08 |
| 09-Jun-10 | 19-Nov-08 | | 05-Dec-08 |
| 27-May-10 | 19-Mar-09 | | 19-Nov-08 |
| 07-May-10 | 22-Jan-09 | | 13-Nov-08 |
| 11-Feb-10 | 31-Oct-08 | | 06-Nov-08 |
| 30-Nov-09 | 28-Oct-08 | | 29-Oct-08 |
| 17-Feb-10 | 29-Oct-08 | | 31-Oct-08 |
| 28-Oct-09 | 31-Mar-09 | | 16-Jun-09 |
| 29-Jun-10 | 13-May-10 | | 22-Jan-09 |
| 13-May-10 | 13-Nov-08 | | 01-Dec-08 |
| 25-May-10 | 21-Nov-08 | | 16-Mar-09 |
| | 14-Nov-08 | | 06-Mar-09 |
| | 20-Nov-08 | | 31-Mar-09 |
| | 23-Mar-09 | | 11-Feb-10 |
| | 30-Jul-09 | | 24-Nov-08 |
| | 01-Jun-10 | | 04-Feb-09 |
| | 07-May-10 | | 12-Feb-09 |
| | 11-Feb-10 | | 14-May-09 |
| | 04-Nov-08 | | 07-May-10 |
| | 26-Mar-09 | | |
| | 06-Mar-09 | | |
| | 17-Apr-09 | | |
| | 16-Jun-09 | | |
| | 12-Feb-09 | | |
| | 24-Nov-08 | | |

Table 8 compares the beta estimates obtained using standard OLS with those obtained through the iterative regression giving less weight to outliers and through a regression with all influential outliers removed. Figure 33 and Figure 38 then plot the rolling estimates of the betas for BT and the other UK utilities against the FTSE. They compare the results of the standard OLS regression, robust regressions and regressions omitting all "outliers". The broad similarity between the standard beta estimates and the other estimates provides confidence that outliers are not driving the shape of our results.

**Table 8: Influential outliers – up-to-date data**

| | 1 yr | | | | 2 yr | | | |
|---|---|---|---|---|---|---|---|---|
| | Standard | Robust | No Outliers | Number of Outliers | Standard | Robust | No Outliers | Number of Outliers |
| *BT* | | | | | | | | |
| All World | 0.86 | 0.92 | 0.86 | 16 | 0.67 | 0.68 | 0.67 | 30 |
| All Share | 0.96 | 0.96 | 0.96 | 6 | 0.84 | 0.89 | 0.78 | 24 |
| **UK Utility Peer Group** | | | | | | | | |
| *National Grid* | | | | | | | | |
| All World | 0.53 | 0.46 | 0.53 | 12 | 0.40 | 0.38 | 0.40 | 33 |
| All Share | 0.52 | 0.48 | 0.52 | 11 | 0.62 | 0.52 | 0.62 | 27 |
| *Northumbrian Water* | | | | | | | | |
| All World | 0.45 | 0.46 | 0.45 | 11 | 0.34 | 0.37 | 0.34 | 30 |
| All Share | 0.46 | 0.51 | 0.46 | 8 | 0.53 | 0.53 | 0.53 | 32 |
| *Pennon Group* | | | | | | | | |
| All World | 0.45 | 0.44 | 0.45 | 14 | 0.42 | 0.40 | 0.42 | 39 |
| All Share | 0.47 | 0.51 | 0.47 | 16 | 0.60 | 0.57 | 0.60 | 30 |
| *Severn Trent* | | | | | | | | |
| All World | 0.42 | 0.45 | 0.42 | 17 | 0.39 | 0.39 | 0.39 | 30 |
| All Share | 0.38 | 0.42 | 0.38 | 13 | 0.53 | 0.51 | 0.53 | 32 |
| *United Utilities* | | | | | | | | |
| All World | 0.42 | 0.49 | 0.42 | 14 | 0.40 | 0.43 | 0.40 | 32 |
| All Share | 0.40 | 0.43 | 0.40 | 11 | 0.54 | 0.53 | 0.54 | 30 |

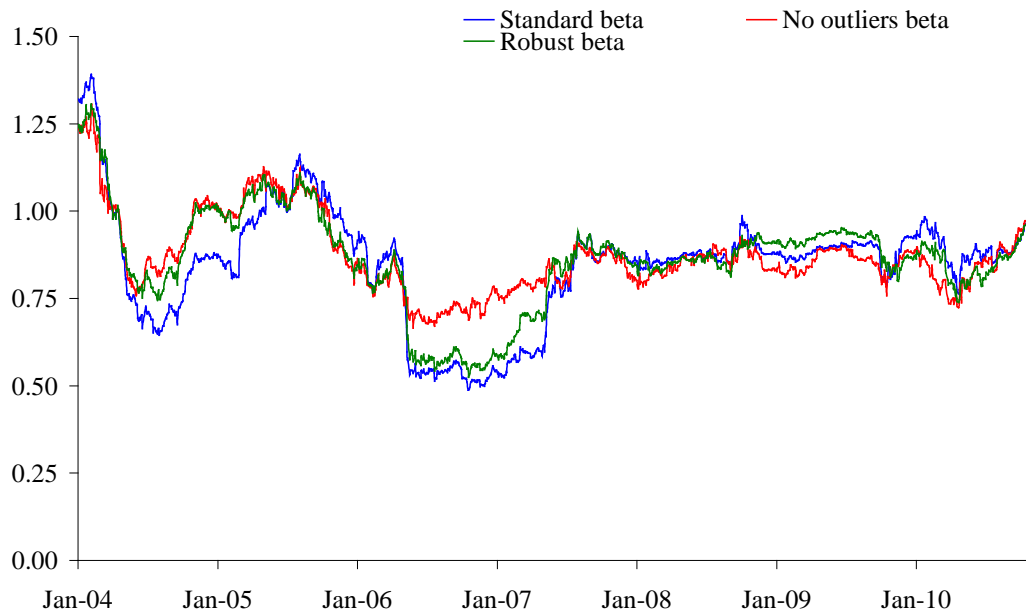**Figure 33: One-year beta against FTSE All-Share – BT**



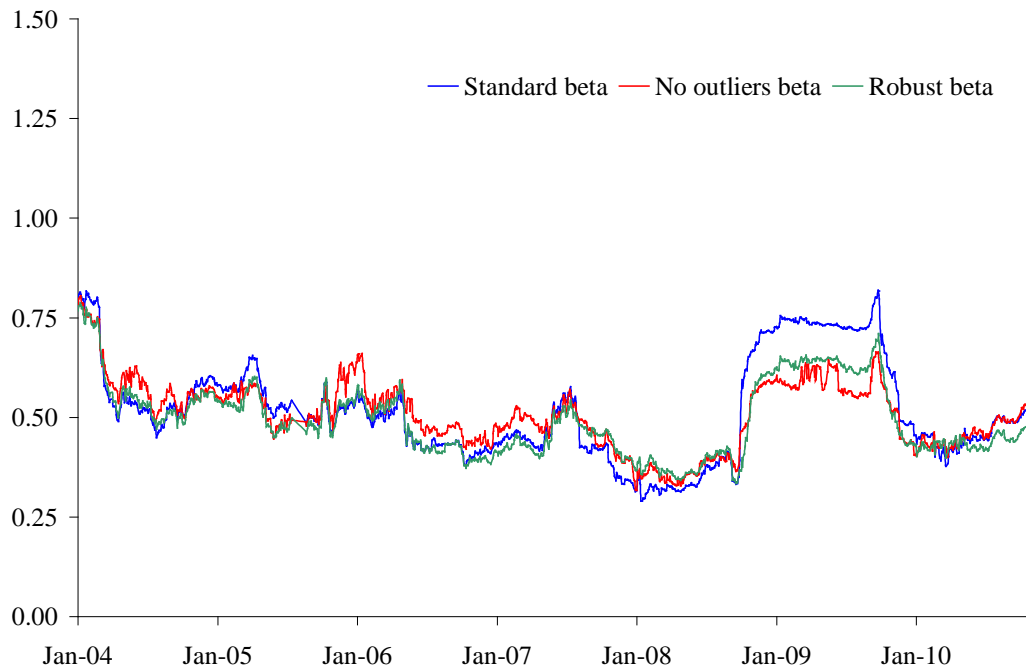**Figure 34: One-year beta against FTSE All-Share – National Grid**

**Figure 35: One-year beta against FTSE All-Share – Northumbrian Water**
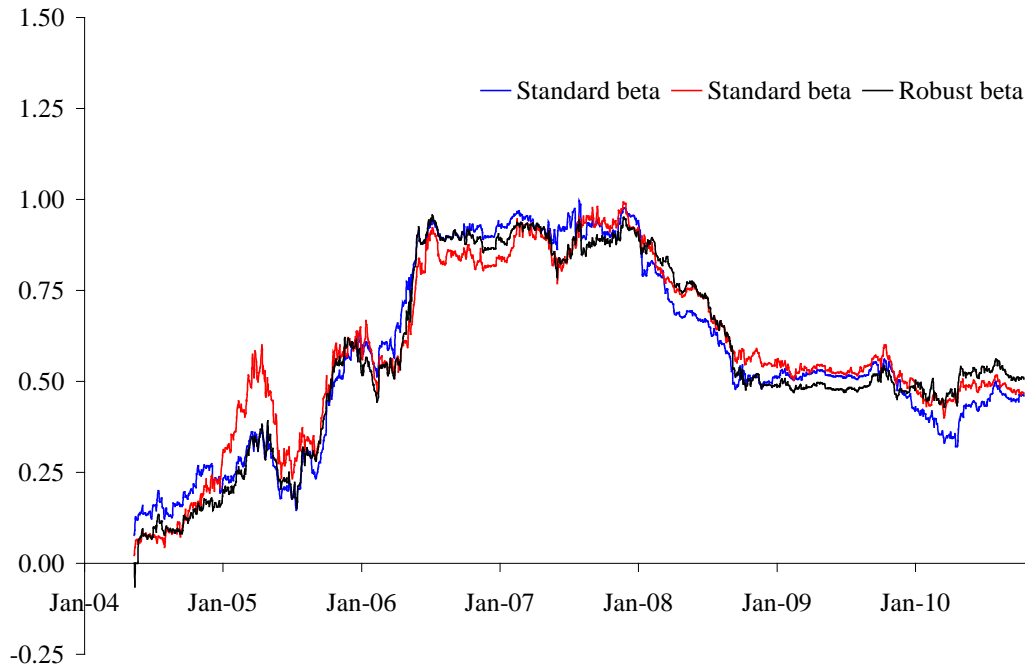


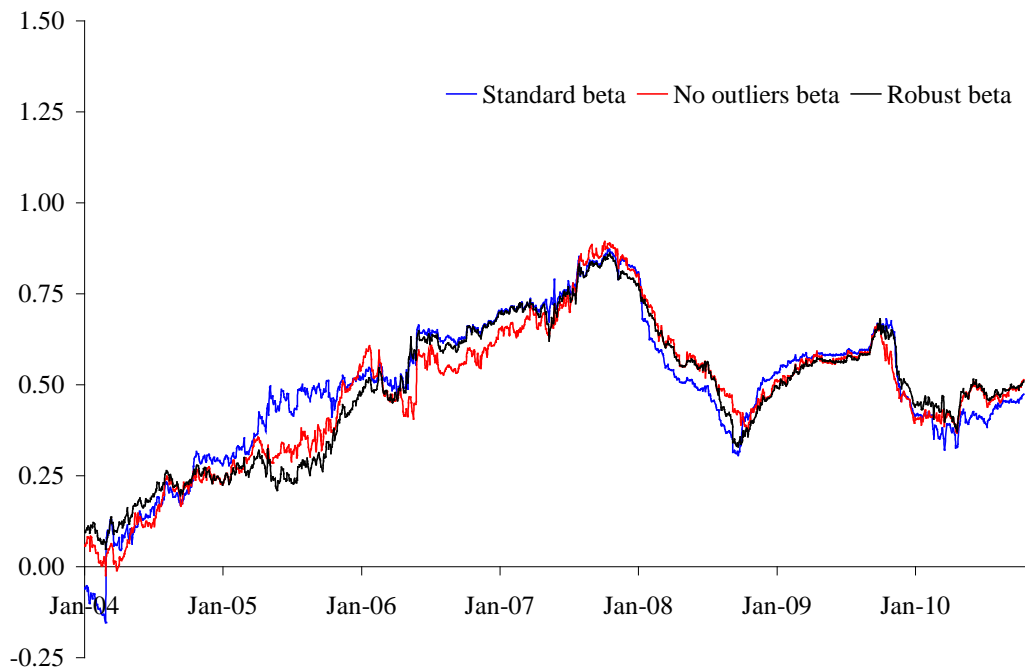**Figure 36: One-year beta against FTSE All-Share – Pennon Group**

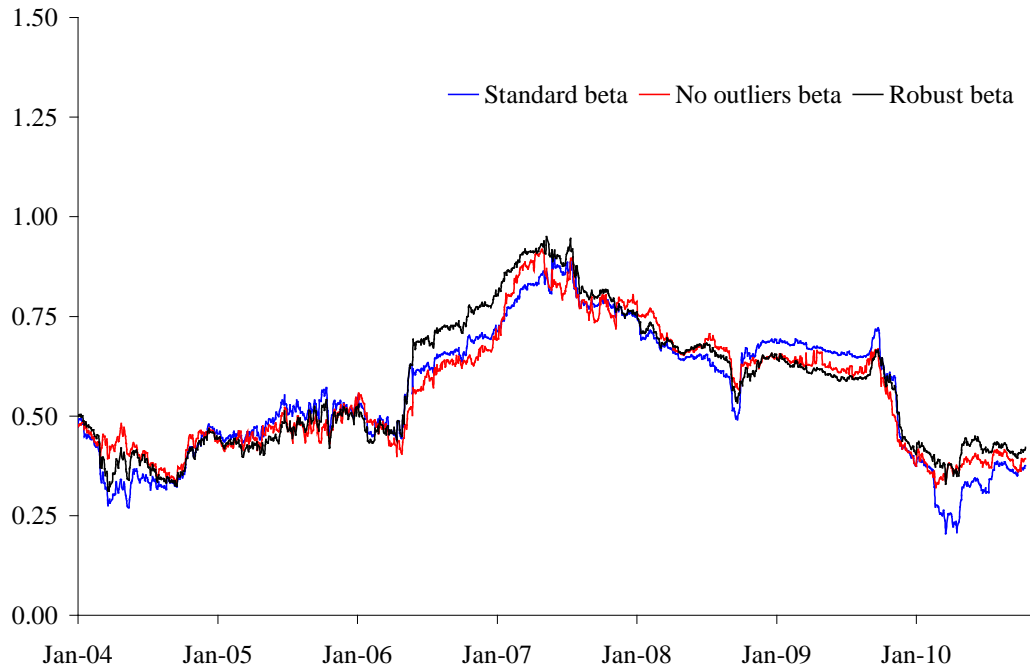**Figure 37: One-year beta against FTSE All-Share – Severn Trent**



**Figure 38: One-year beta against FTSE All-Share – United Utilities**