ESTIMATE OF BT'S EQUITY BETA

JULY 2011

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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 five other publicly traded UK utilities: 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 five liquidly traded US telecommunications stocks. The companies in our US sample all focus to varying degrees 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). Three of the US companies are pure-play wireline, while two provide wireless and other services as well. The US telecommunications sample is interesting in part because it reflects risks associated with the provision of local loop services of relevance to BT.

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 telecommunications services accounted for 39% of BT's 2010 revenues and 30% of 2010 EBITDA. Likewise, not even any of the 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 makes the other 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

[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.

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 June 6 2011.

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.

[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 June 6, 2011.

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

	1 Yr				2 Yr			
	Beta	SE	Low	High	Beta	SE	Low	High
BT								
All World	0.91	0.11	0.69	1.13	0.80	0.09	0.63	0.97
All Share	0.94	0.09	0.77	1.12	0.91	0.07	0.78	1.05
UK Utility Peer Group								
National Grid								
All World	0.57	0.08	0.41	0.73	0.45	0.05	0.34	0.55
All Share	0.59	0.06	0.46	0.71	0.50	0.04	0.41	0.58
Northumbrian Water								
All World	0.44	0.09	0.27	0.61	0.37	0.06	0.25	0.50
All Share	0.51	0.07	0.37	0.64	0.46	0.05	0.36	0.56
Pennon Group								
All World	0.57	0.08	0.41	0.72	0.40	0.06	0.29	0.52
All Share	0.61	0.06	0.49	0.73	0.48	0.05	0.39	0.58
Severn Trent								
All World	0.52	0.08	0.37	0.67	0.38	0.06	0.27	0.50
All Share	0.55	0.06	0.43	0.67	0.42	0.05	0.33	0.51
United Utilities								
All World	0.52	0.08	0.37	0.67	0.39	0.05	0.28	0.50
All Share	0.54	0.06	0.42	0.66	0.43	0.04	0.35	0.52
Peer Group Average								
All World	0.52				0.40			
All Share	0.56				0.46			

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 0.94, compared with our estimate of 0.85 as of March 2009. We estimate an up-to-date two–year equity beta of 0.91, compared with our estimate of 0.85 as of March 2009. The 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 several years, despite the spike in price volatility at the end of 2008 and the first quarter of 2009. Although the two-year beta has remained relatively stable, both the rolling sixth month and one-year betas display some volatility. Since 2008, the one-year beta has varied

[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.

between a low of 0.78 and a high of 1.09, while the sixth month estimate declined to a low of 0.49 in the first half of 2010 before climbing back to 1.16 by the end of the year.

Figure 1: BT rolling betas

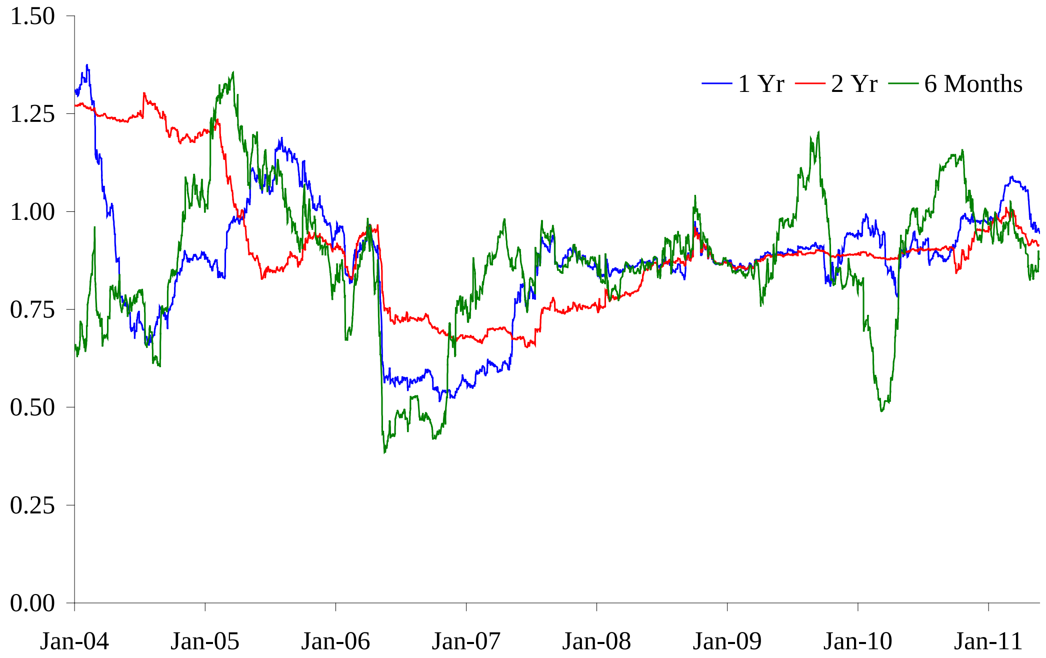


Table 1 highlights that BT's equity beta comes in higher than the rest of the UK utility reference sample. Both BT's one- and two-year equity betas are now almost double the average of the other UK utilities (0.94 vs 0.56 for the one-year, 0.91 vs 0.46 for the two-year). The gap between BT and the other 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 is apparent in the one-year estimates.

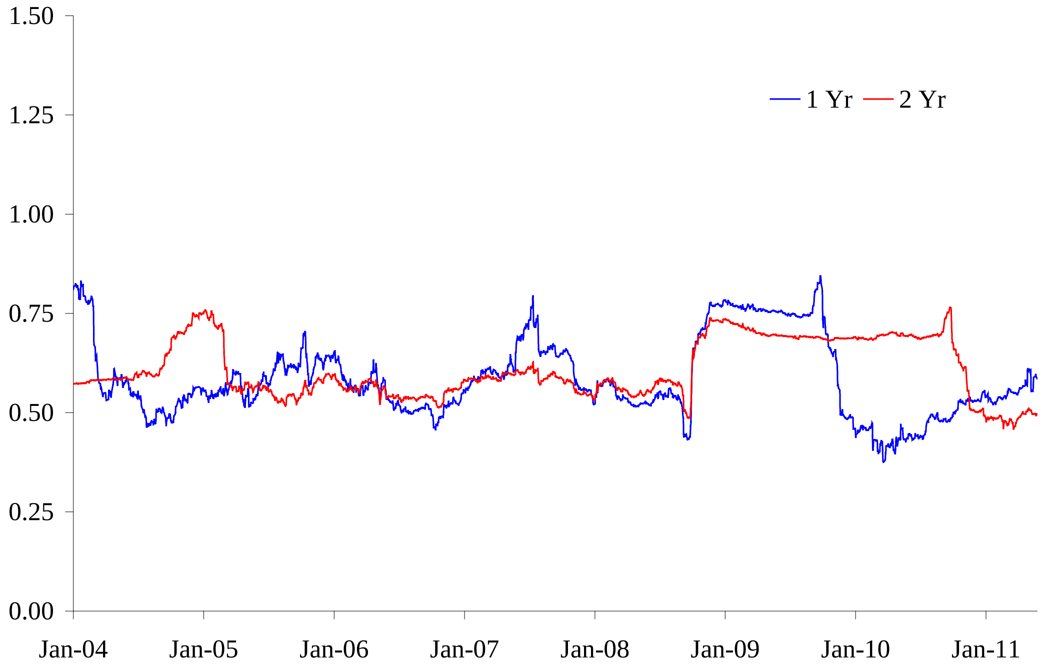
Figure 2 to Figure 6 plot one and two-year betas for the other UK utilities against the FTSE All-Share. National Grid, Pennon Group, Severn Trent and United Utilities see movement in the equity beta during the last few months of 2008. Then in 2009, the one-year estimates fall off dramatically towards 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. In more recent periods the one-year betas trend upwards towards previous levels. The effect is somewhat less extreme for Northumbrian Water and Pennon Group.

Underlying the 2008/2009 downward trend in the one-year betas may be a step change in investors' risk perception of utilities after the collapse of Lehman, as part of a fundamental re-evaluation of risk and "flight to safety". Of course, such a change in risk perceptions would flow through more slowly to the two-year beta estimate as post-Lehman data replaced pre-crisis data in the data window. And as we might have expected, we find that the step change in the one-year estimates is matched by corresponding changes in the two-year estimates a year later as pre-crisis data leaves the data window.. More recently, we see an upward trend in the one-year beta estimates for the utility reference sample, perhaps reflecting the reversion of investors' risk perceptions to pre-crisis levels.

What is striking is the contrasting lack of any similar movements in the one- or two-year estimates for BT. Both BT's one and two-year betas have remained comparatively steady, while the betas for the other utilities declined and somewhat rebounded. 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 and more recent rebound in the one-year betas for National Grid and some of the other utilities may reflect no more than noise in the data. 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 particular points on the estimates. We find that the standard OLS betas for BT and the utility reference sample are broadly robust to the exclusion or underweighting of influential data points.

Figure 2: National Grid rolling betas



[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 3: Northumbrian Water rolling betas

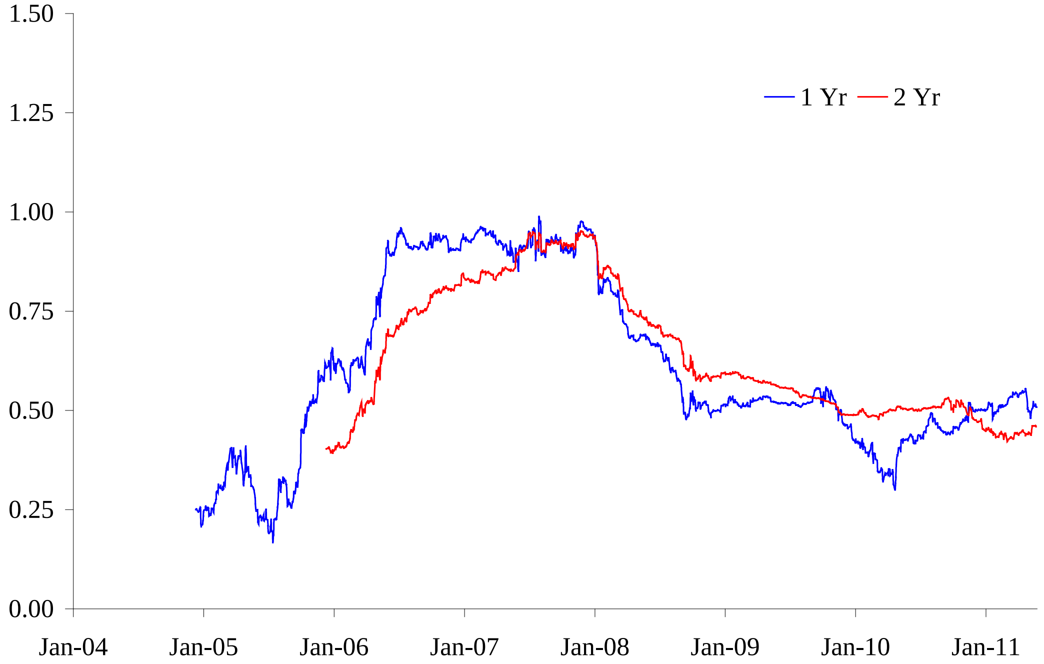


Figure 4: Pennon Group rolling betas

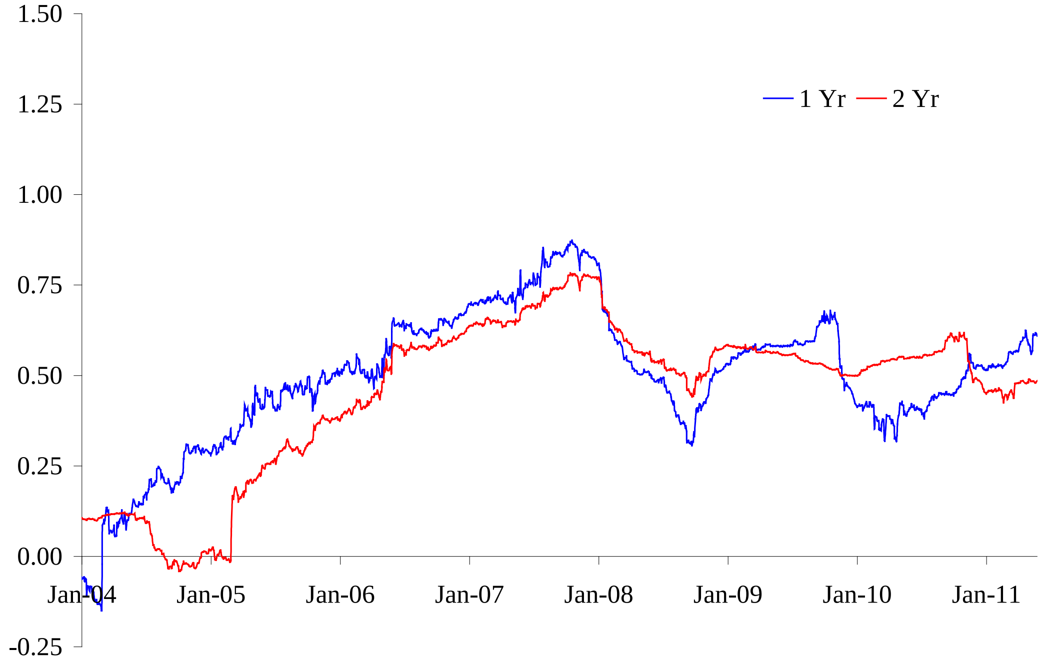


Figure 5: Severn Trent rolling betas

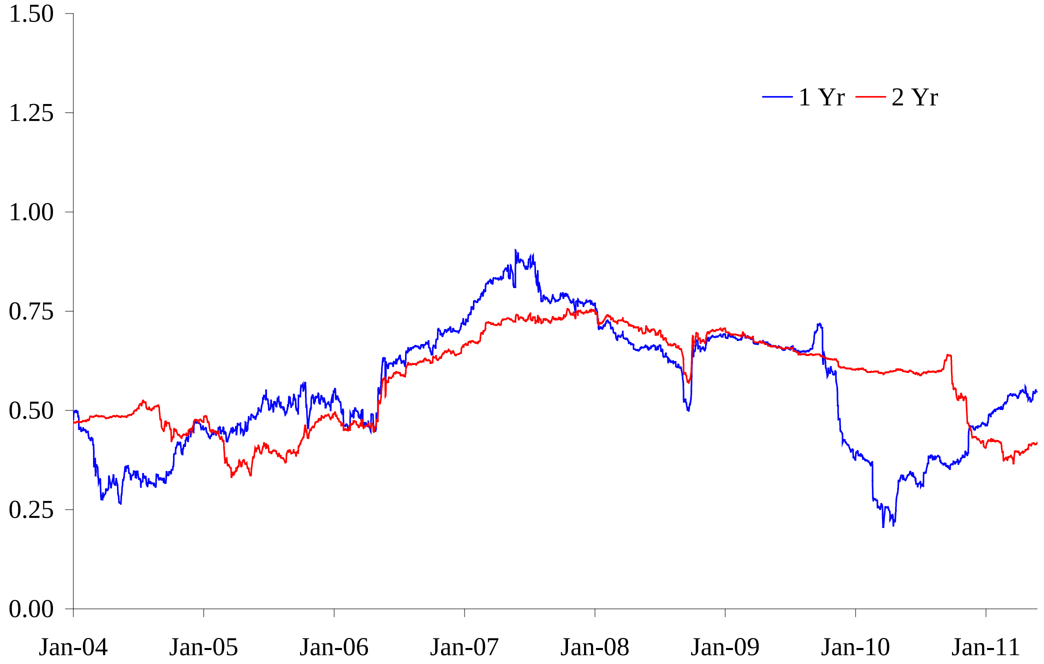
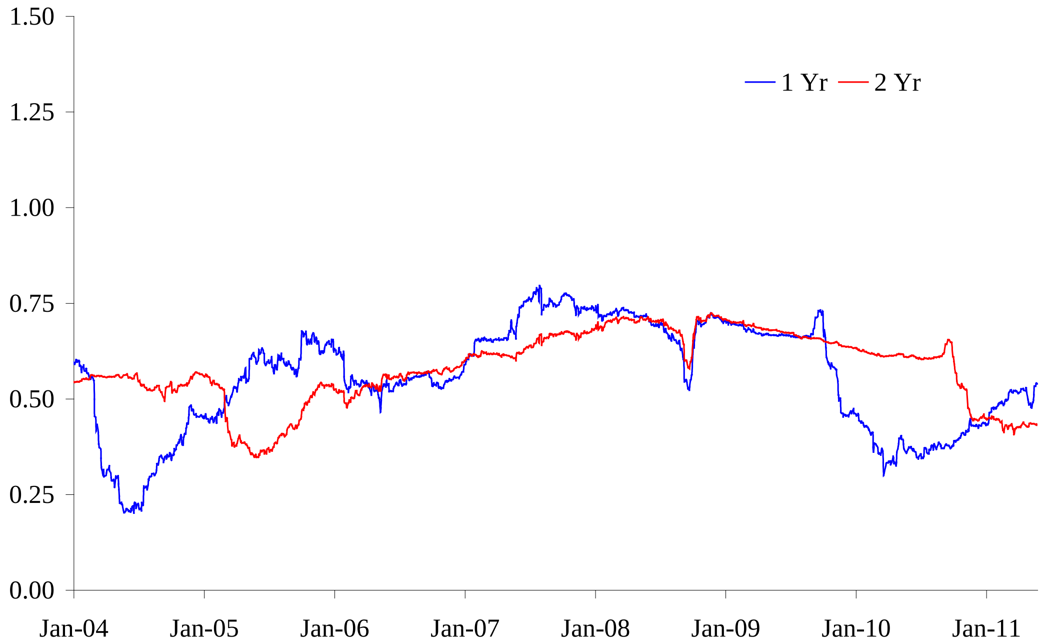


Figure 6: United Utilities rolling betas



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. This view may be consistent with the recent upward trend in one-year betas as investors have 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 investor 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.

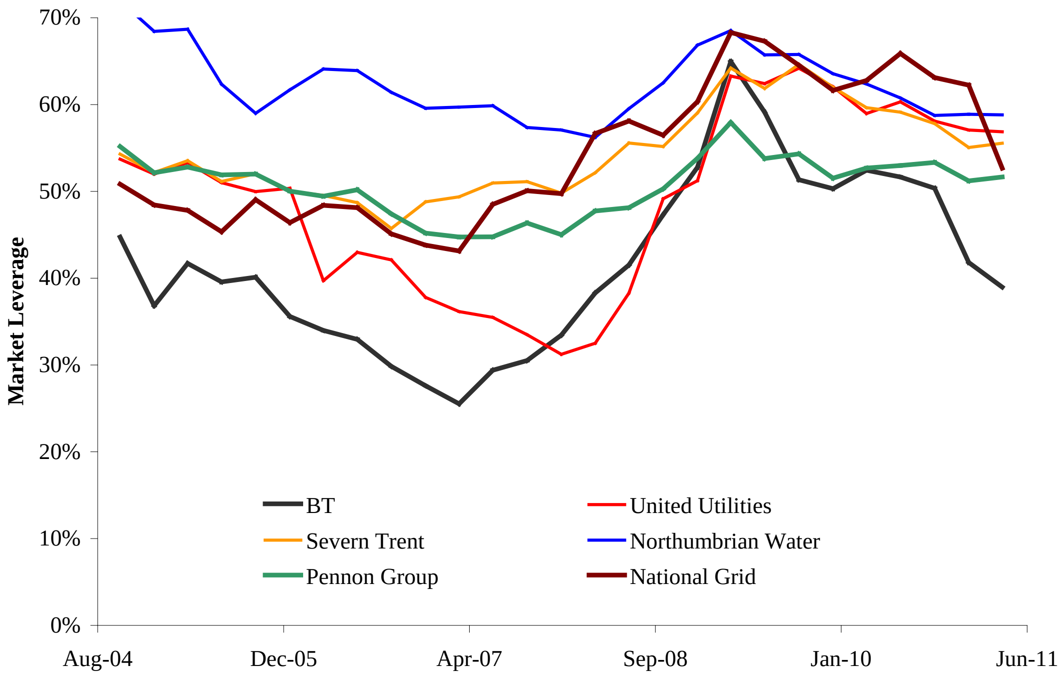
We check the potential impact of the financial crisis on financial leverage by estimating the market price of BT's debt. Much of BT's long-term debt is publicly traded. We obtained available data concerning debt prices and yields. The available data indicates that the market price of BT's debt declined somewhat at the end of 2008 during the height of the crisis, but not to such 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 affect the asset beta by as little as 3%.[7]

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

[7] Suppose we perceived a gearing ratio of 40% on the assumption that the book value of debt were a good proxy for market value. Now, suppose that the market value were 10% less than book value. The true gearing ratio therefore would be 37.5% (36 / 36+60). Unlevering BT's latest two-year equity beta of 0.91 assuming gearing of 40% and a debt beta of 0.15, we would derive an asset beta of 0.61. Assuming gearing of 37.5%, we would derive an asset beta of 0.625, or only 3% higher than that derived using the book value of debt.

assumption about the stability of the market-to-book ratios for 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 witnessed a substantial rise in leverage after 2007. BT actually maintained a relatively stable stock of debt over the period, but its share price dropped dramatically during 2008. The same level of debt combined with less equity, so that leverage doubled from 30% to just over 60% by the end of 2008. The share price has since rebounded somewhat, and has prompted a substantial 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 asset beta estimates for BT and the utility sample, illustrating the betas that we would expect if all of the companies maintained only equity financing. We use two separate approaches to un-lever the raw equity beta estimates. The first approach uses the simplest possible un-levering formula and assumes that the debt beta is zero.[8] 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 for beta. In other words, when focussing on one-year betas, we estimate average leverage across the one-year measurement window. When

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

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 illustrate a slight widening of the gap between BT and the other UK utilities since the onset of the credit crisis. A further figure compares one- and two-year asset betas for BT.

Table 2: "Asset" betas

	1 Year		2 Year	
	β debt = 0	*β debt = 0.15*	*β debt = 0*	*β debt = 0.15*
BT				
All World	0.48	0.55	0.40	0.47
All Share	0.50	0.57	0.45	0.53
UK Utility Peer Group				
National Grid				
All World	0.22	0.31	0.16	0.26
All Share	0.22	0.32	0.18	0.28
Northumbrian Water				
All World	0.18	0.27	0.14	0.23
All Share	0.21	0.29	0.17	0.27
Pennon Group				
All World	0.27	0.35	0.19	0.27
All Share	0.29	0.37	0.23	0.31
Severn Trent				
All World	0.22	0.31	0.16	0.25
All Share	0.23	0.32	0.17	0.26
United Utilities				
All World	0.22	0.31	0.16	0.25
All Share	0.23	0.31	0.17	0.26
Peer Group Average				
All World	0.22	0.31	0.16	0.25
All Share	0.24	0.32	0.18	0.27

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

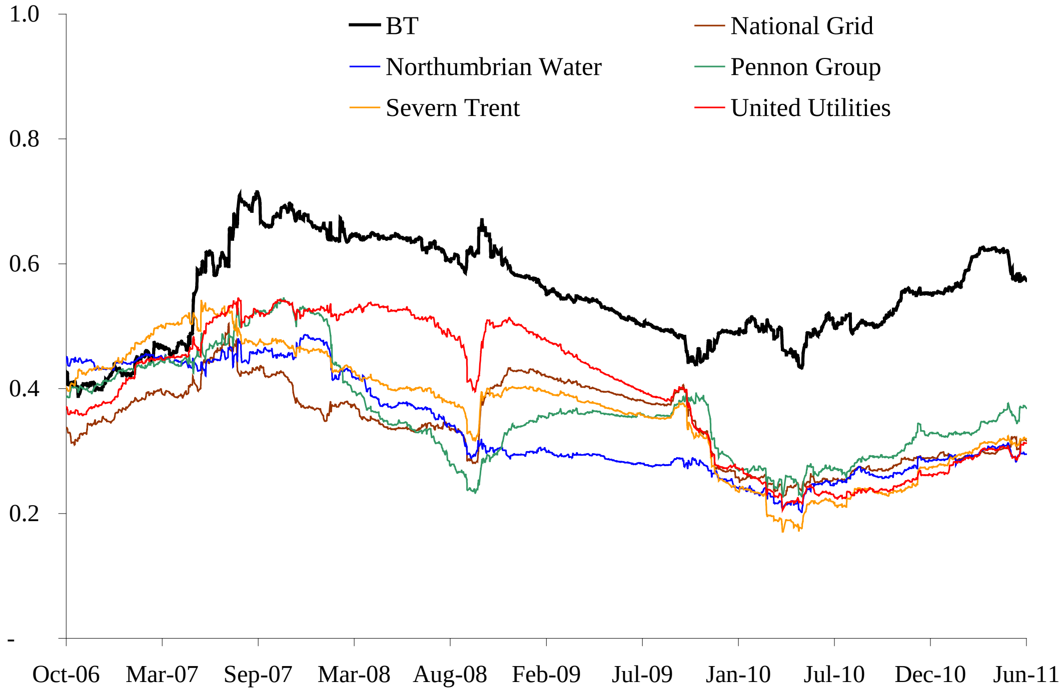


Figure 9: Two-year asset betas - FTSE All-Share

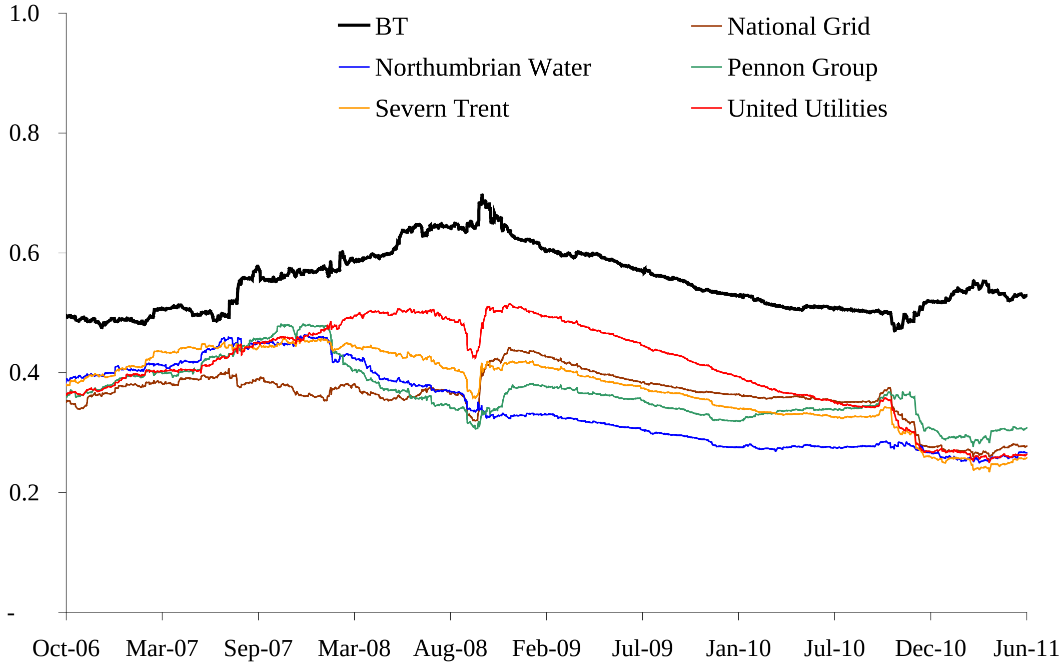
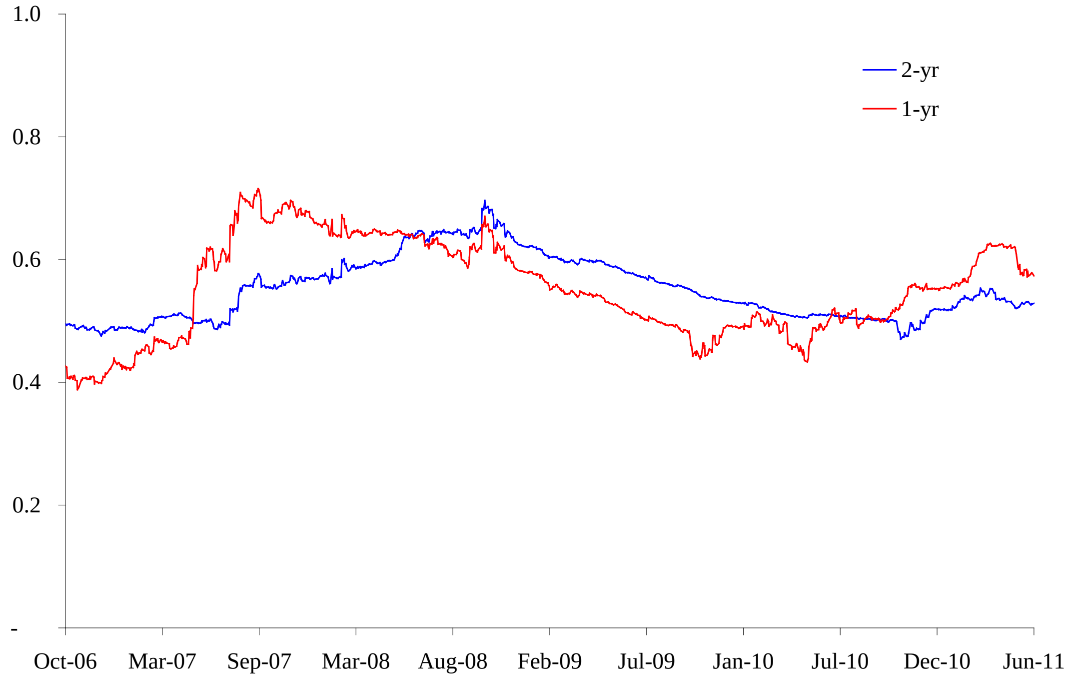


Figure 10: One and two year asset betas – BT vs FTSE All-Share



2.3 US Telecoms

In addition to the UK utility reference sample, we examined data for five US telecommunications companies: Frontier, Qwest[9], Windstream, AT&T and Verizon. Three of the companies are pure-play wireline (Frontier, Qwest and Windstream), meaning that the core activities of these companies involves local loop access and the provision of associated telephone services such as local telephone calls and retail broadband. Two of the companies (AT&T and Verizon) combine both wireline and wireless activities in roughly equal measure.[10] Data for the US telecoms companies is relevant for our purpose to the extent that it reflects businesses whose principal activities include to a significant extent access to the local loop.

Using the standard techniques, we estimated asset betas for each of the five US telecoms companies. Figure 11 to Figure 12 plot the development of the asset betas over time. Over most of the period, asset betas for the three pure-play US wireline stocks against the S&P 500 come in below the level for BT against the FTSE All-Share. More recently, the gap between BT and the remaining two pure-play wireline stocks has grown. While the US pure-play wireline asset betas have either declined or remained constant, the BT betas have displayed a slight increase.

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[9] Qwest was bought by CenturyLink in Apr-11. We stop tracking the beta following the merger announcement on 22nd April 2010. Subsequent movements in the stock price reflect market speculation about the final terms of the deal and thus may be contaminated for the purpose of estimating beta.

[10] AT&T's obtains roughly 55% of revenues from wireline activities, compared with 42% for Verizon.

At the same time, the BT asset beta has grown relative to those of the two integrated large cap US telecoms companies: AT&T and Verizon. The divergence appears in the one-year betas begins at roughly the start of 2010, while the divergence in the two-year estimates begins towards the end of 2010. The timing of the divergence is broadly consistent with the data window passing autumn 2008 and the heart of the credit crisis. Since then, investors appear to have viewed BT as distinct and slightly more risky than AT&T or Verizon, while they have viewed AT&T and Verizon as only slightly more risky than the pure-play wireline stocks.

Figure 11: One-year asset betas of US sample

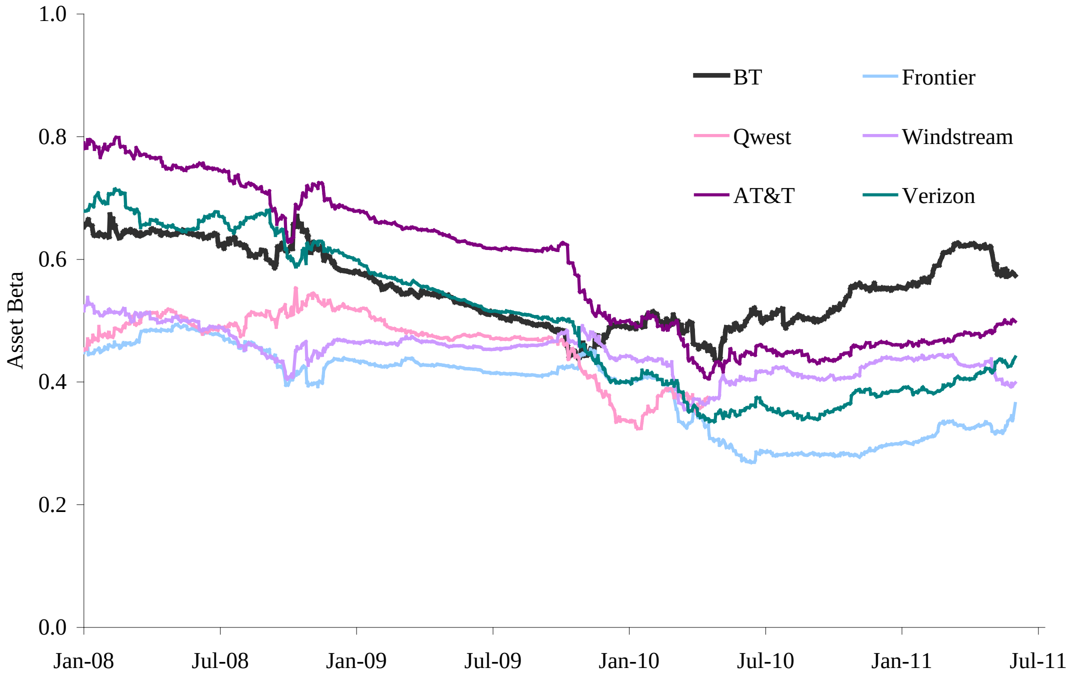
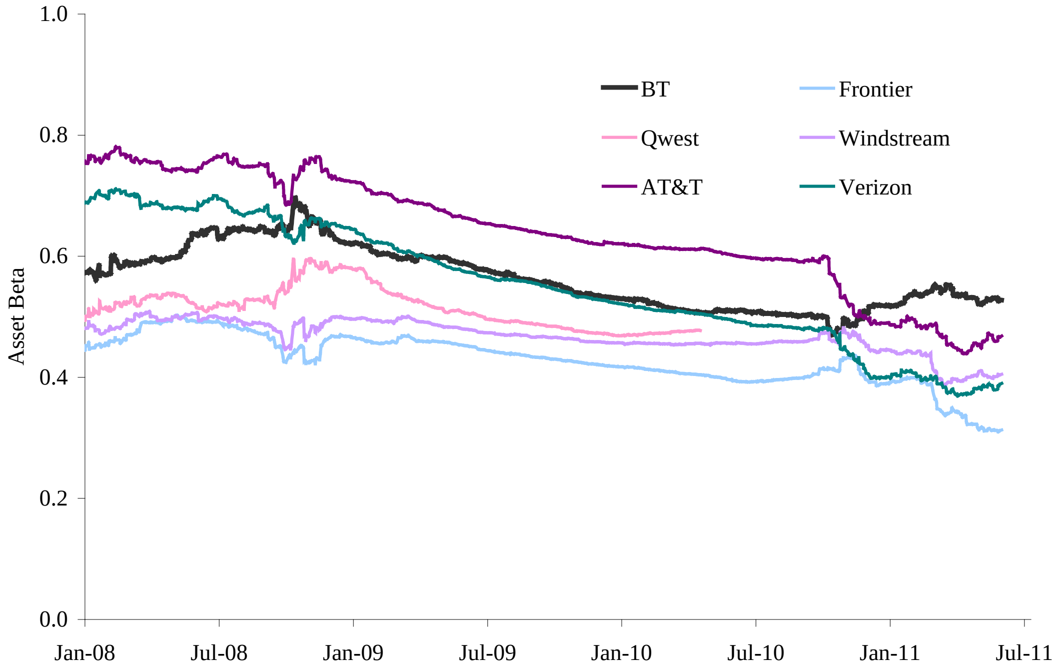


Figure 12: Two-year asset betas for US sample



2.4 Conclusions

We remain concerned about the large swing in BT's financial leverage over the past few years and its implications for our beta calculations. BT's financial leverage more than doubled to over 60% during the first half of 2009 as a result of a large drop in BT's share price, before falling back somewhat due to a share price rebound. 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 0.94 against the FTSE All-Share. This estimate corresponds with average leverage during the two-year measurement window of 51%, and implies an asset beta for BT of between 0.45 and 0.53. The last year of data generates slightly higher estimates: an equity beta of 0.94 against the FTSE All-Share, corresponding with average leverage of just over 47%. The last year of data implies an asset beta of 0.50 to 0.57. 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 beta has not followed the same general 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 such 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 the poor performance of some of BT's non-core business or uncertainty over the pension fund deficit.

The most recent beta estimates for US telecoms companies remain above those observed for the UK energy and water utilties, but slightly lower than those for BT.

We would normally recommend a range of +/- approximately two standard deviations around our mid-point figures (0.09 for the last year of data, and 0.07 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.[11] 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[12] 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 never 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. We also note that the Dimson adjustments do not appear to change the latest one-year estimates for BT by a substantial amount (0.94 against the All-Share goes down to to 0.92 when we add one-day lead and lag terms). Table 3 reports Dimson betas for the UK utilities.

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

[12] 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. Timing adjustments therefore may be relevant for betas versus the FTSE All-World.

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	0.91	1.04	0.23	Neither lag nor lead	0.80	0.87	0.19	Neither lag nor lead
All Share	0.94	0.92	0.20	Neither lag nor lead	0.91	0.94	0.16	Neither lag nor lead
UK Utility Peer Group								
National Grid								
All World	0.57	0.58	0.15	Neither lag nor lead	0.45	0.49	0.11	Neither lag nor lead
All Share	0.59	0.44	0.14	Neither lag nor lead	0.50	0.44	0.10	Neither lag nor lead
Northumbrian Water								
All World	0.44	0.50	0.17	Neither lag nor lead	0.37	0.33	0.12	Neither lag nor lead
All Share	0.51	0.46	0.15	Neither lag nor lead	0.46	0.39	0.11	Neither lag nor lead
Pennon Group								
All World	0.57	0.58	0.15	Neither lag nor lead	0.40	0.52	0.11	Neither lag nor lead
All Share	0.61	0.50	0.13	Neither lag nor lead	0.48	0.57	0.10	Neither lag nor lead
Severn Trent								
All World	0.52	0.51	0.15	Neither lag nor lead	0.38	0.36	0.12	Neither lag nor lead
All Share	0.55	0.50	0.13	Neither lag nor lead	0.42	0.45	0.11	Neither lag nor lead
United Utilities								
All World	0.52	0.57	0.14	Neither lag nor lead	0.39	0.32	0.11	Neither lag nor lead
All Share	0.54	0.47	0.13	Neither lag nor lead	0.43	0.35	0.10	Neither lag nor lead

3.2 Tests for heteroscedasticity and auto-correlation

We perform a series of 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 13 to Figure 18 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 13: BT - residuals against fitted values

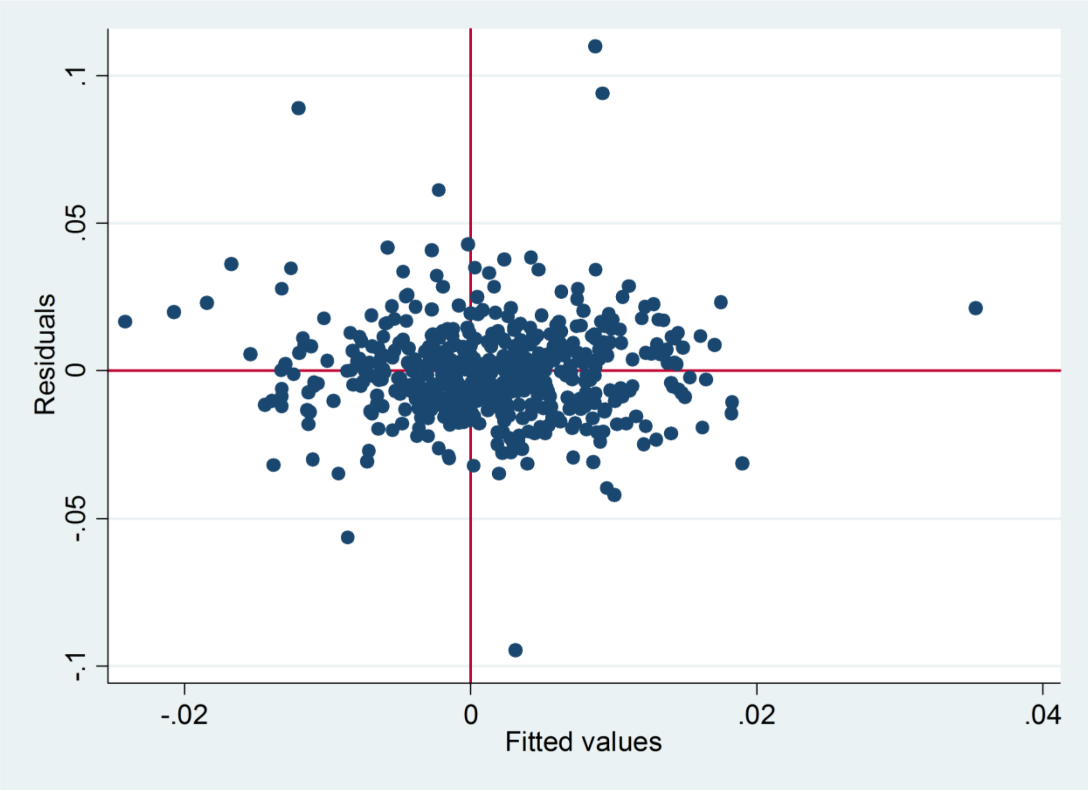


Figure 14: National Grid - residuals against fitted values

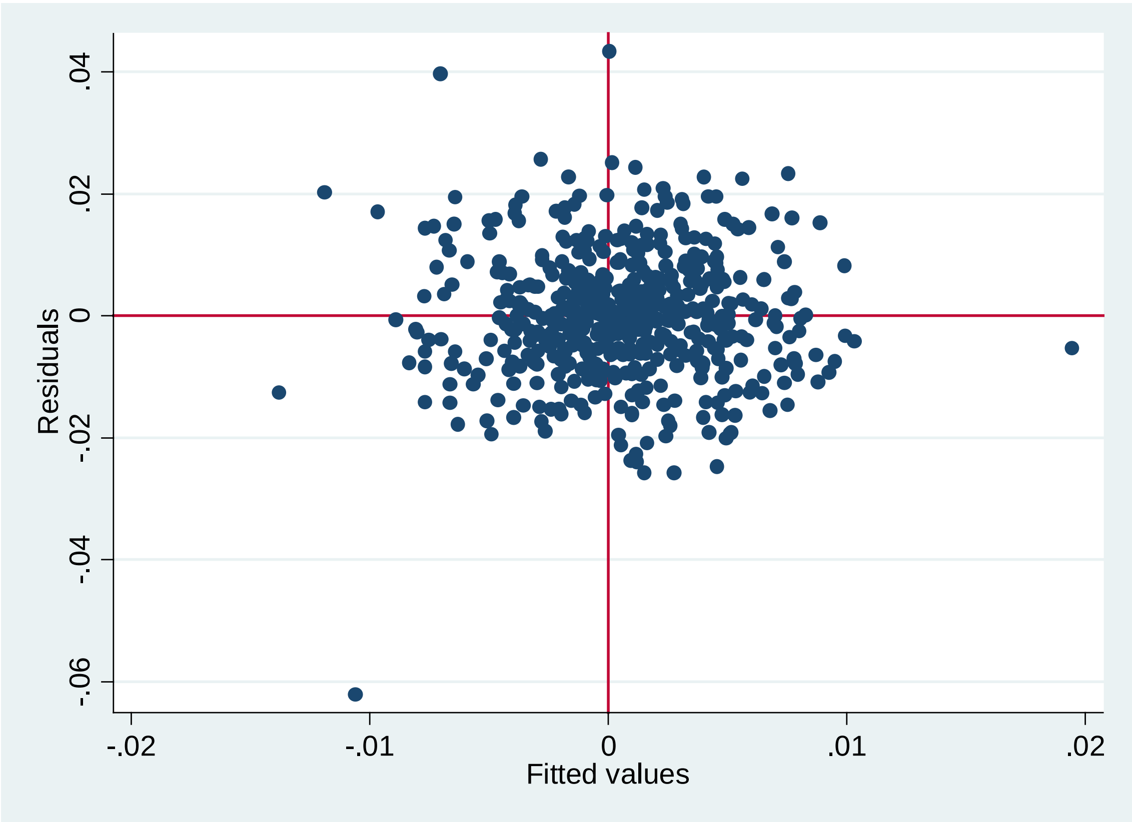


Figure 15: Northumbrian Water – residuals against fitted values

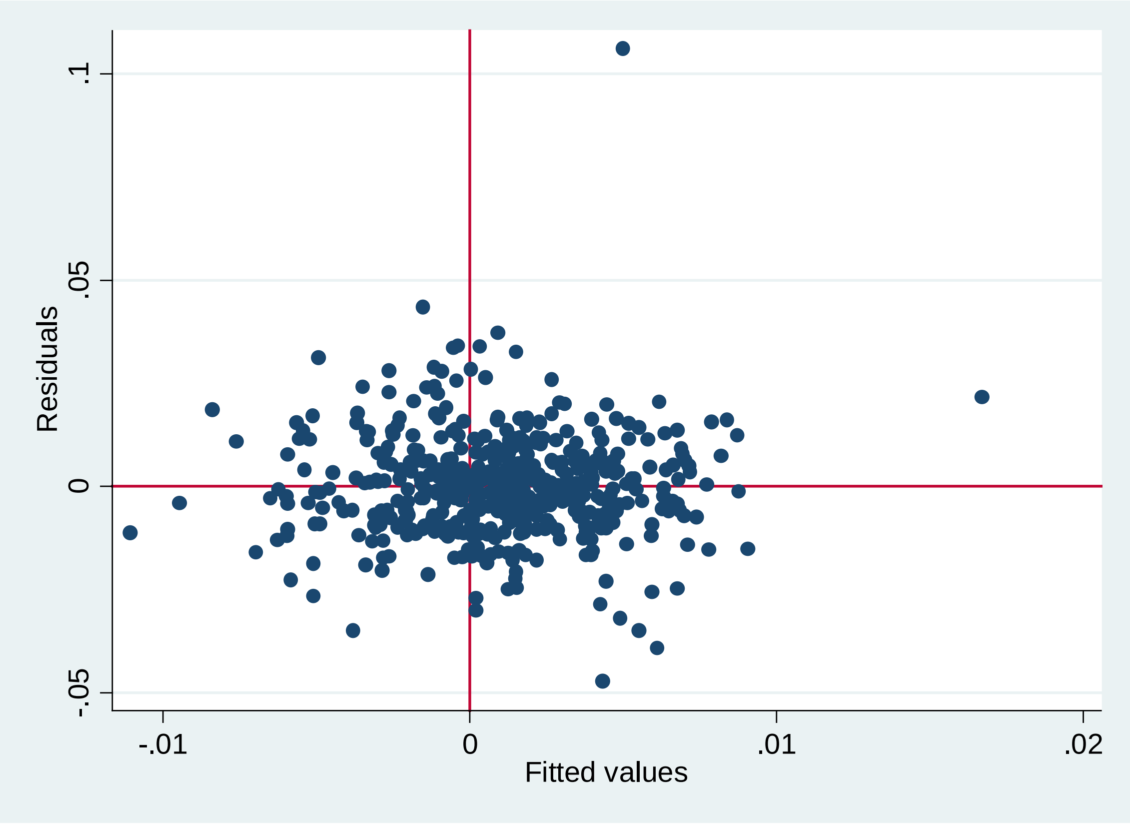


Figure 16: Pennon Group – residuals against fitted values

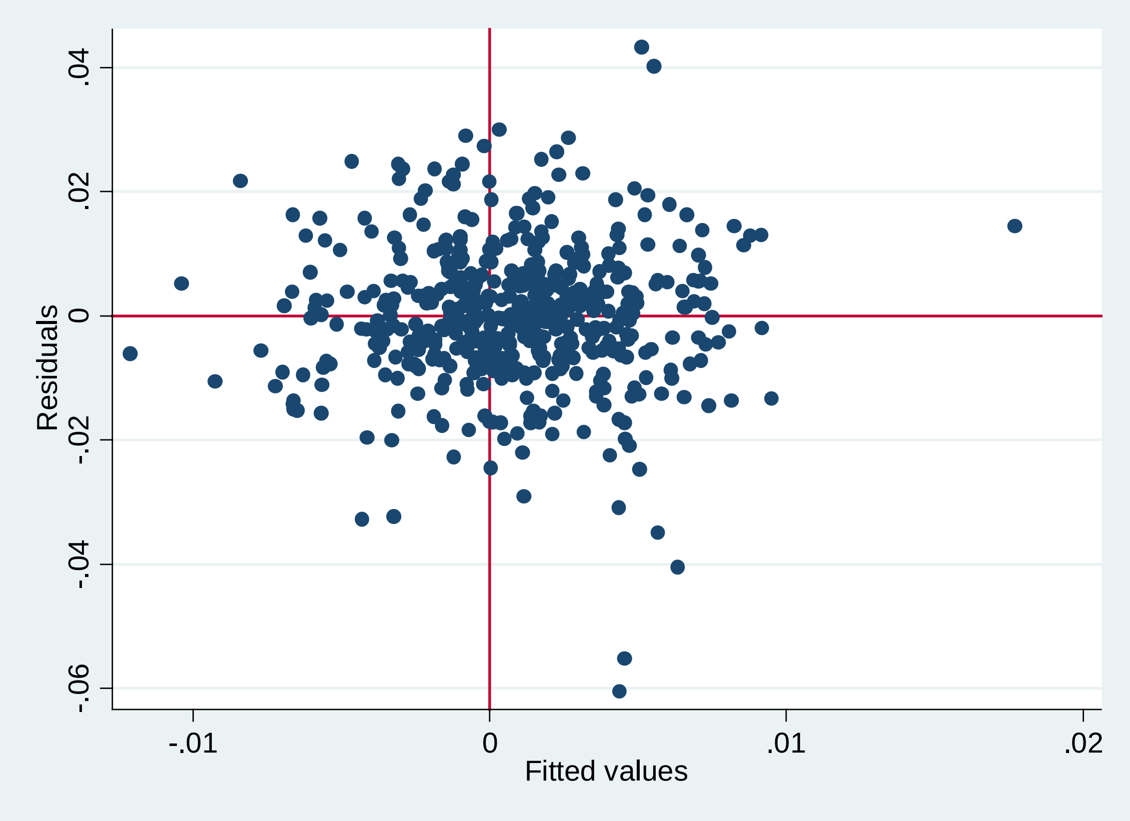


Figure 17: Severn Trent – residuals against fitted values

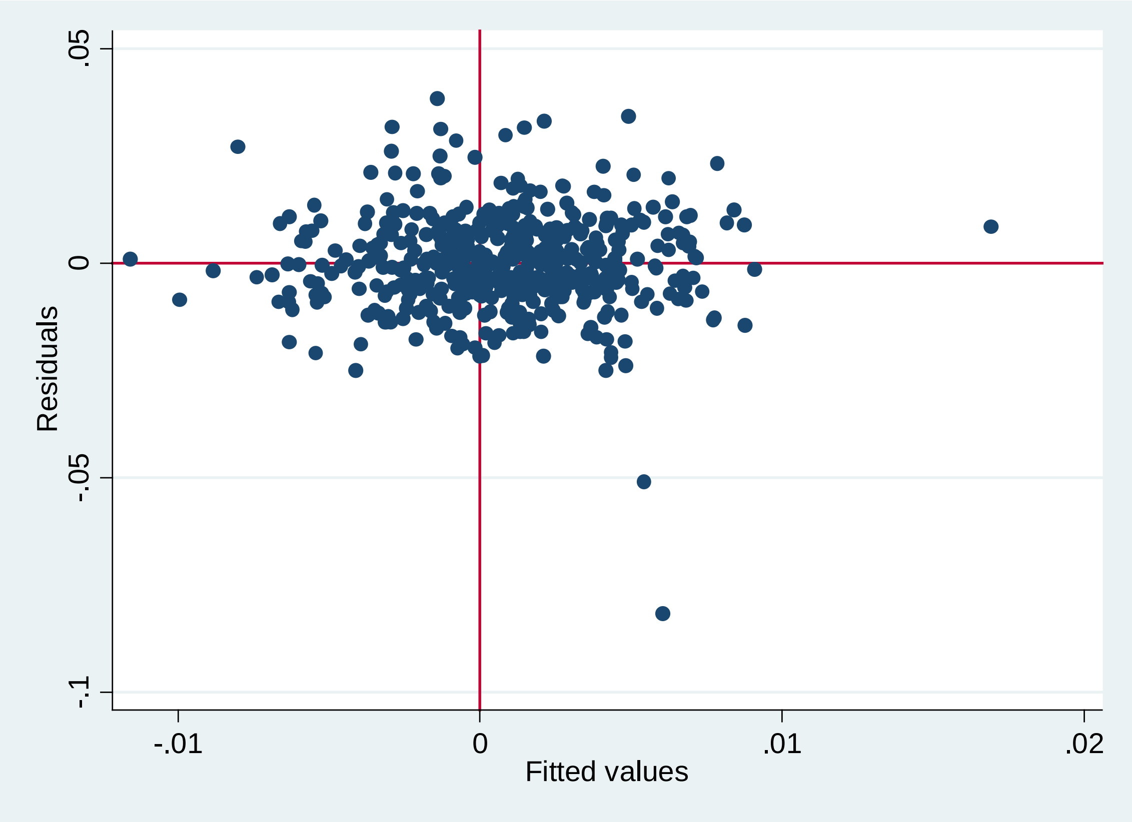
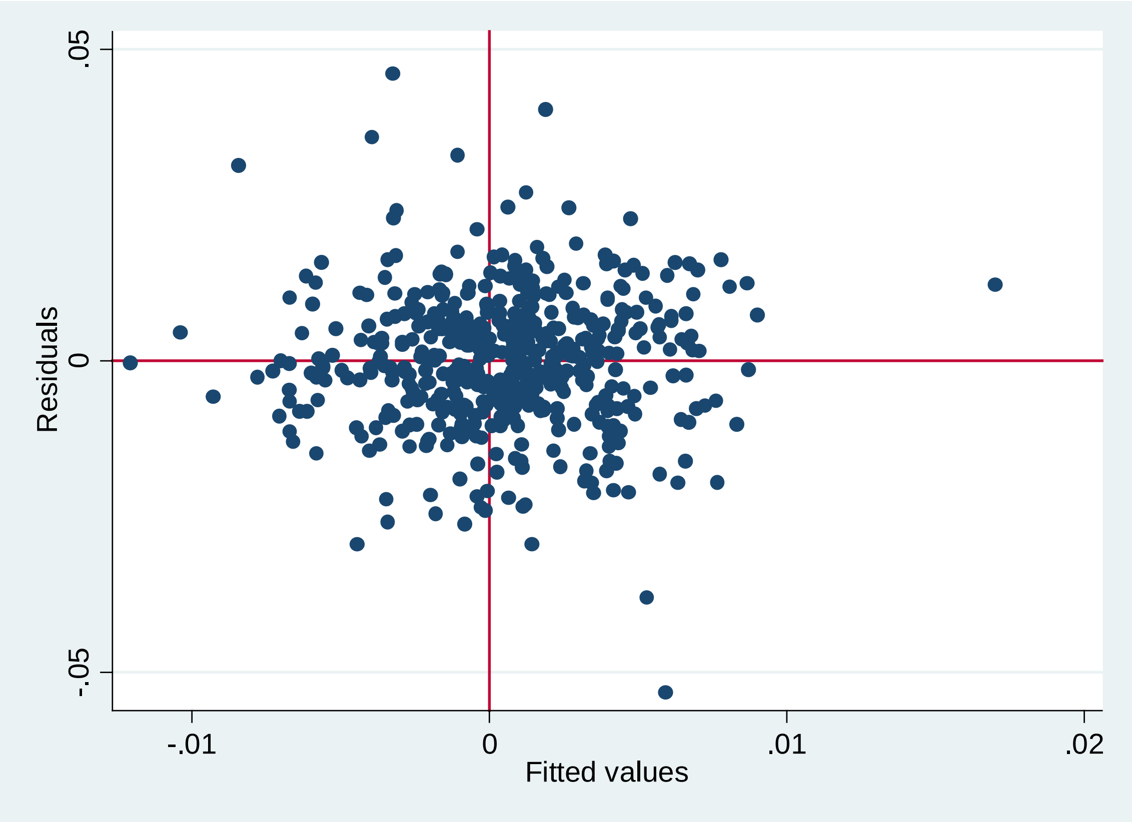


Figure 18: United Utilities – residuals against fitted values



We also examine whether there is change in the pattern of residuals over time. Figure 19 to Figure 24 do not show an apparent pattern of the residuals for the two-years estimation window. The plots again relate to two-year beta estimates calculated against the FTSE All-World.

Figure 19: BT - residuals over time

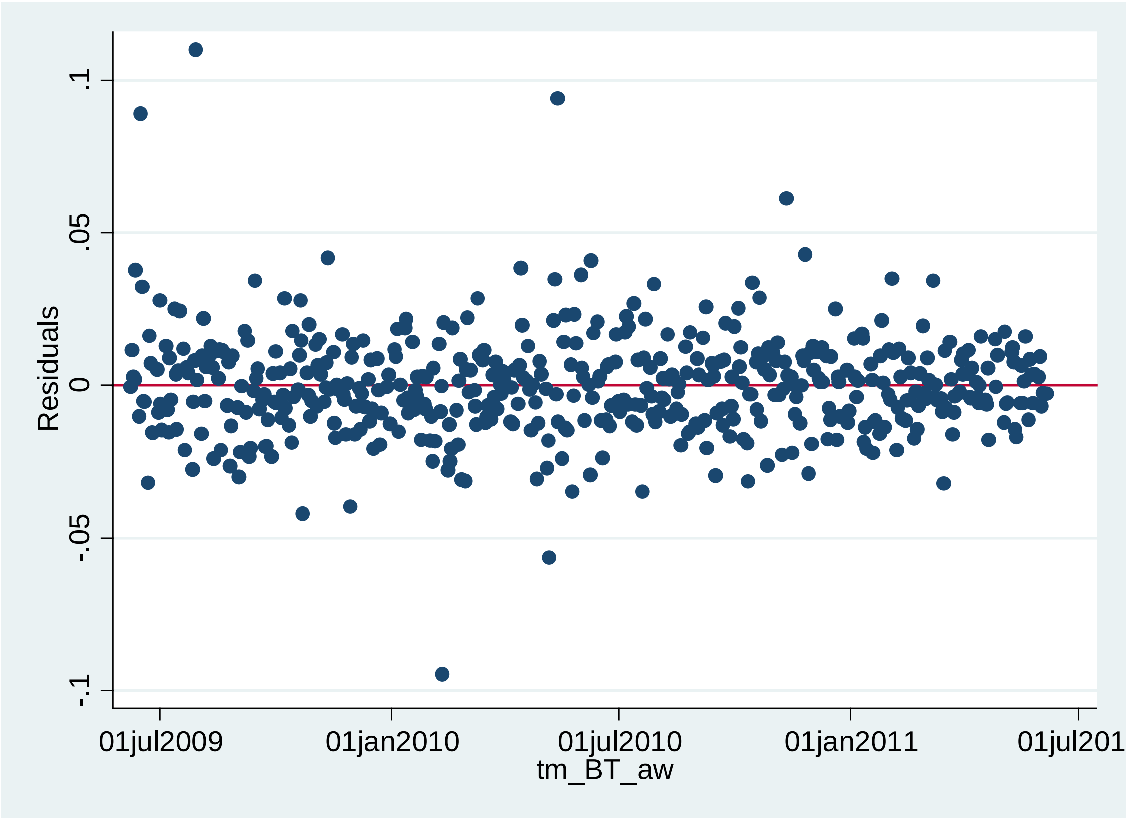


Figure 20: National Grid – residuals over time

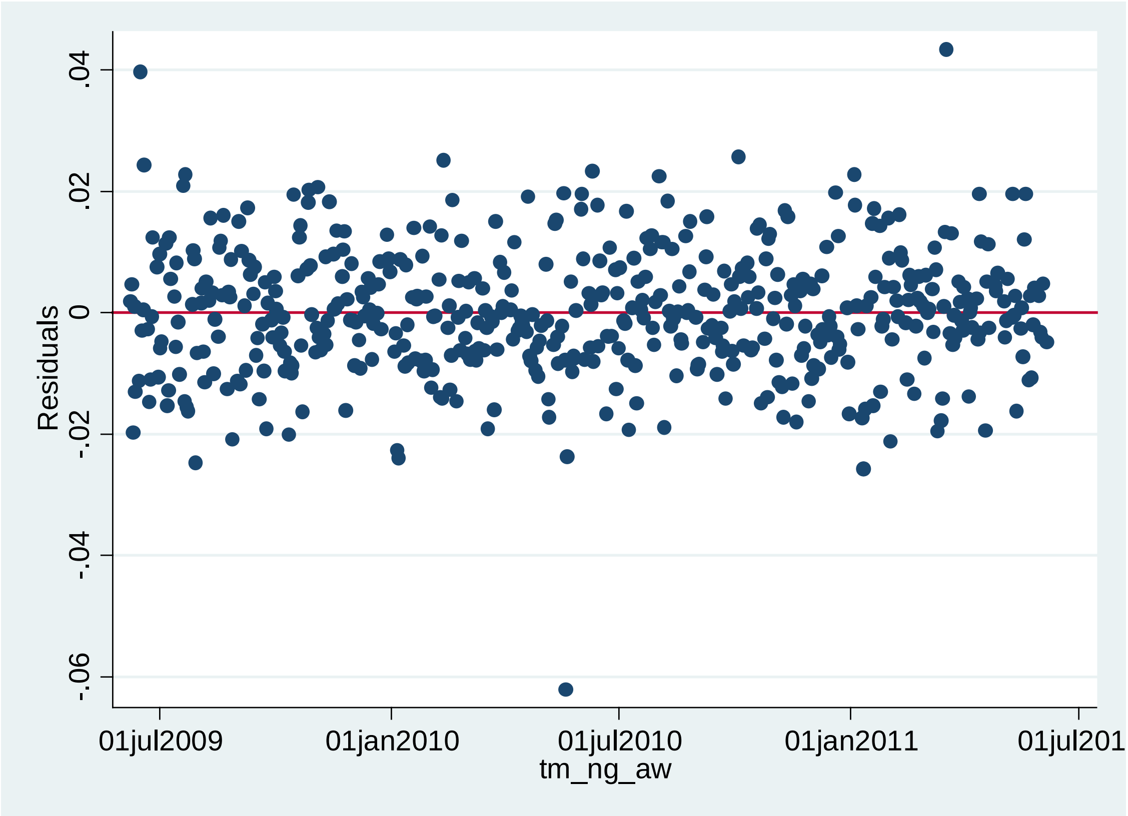


Figure 21: Northumbrian Water – residuals over time

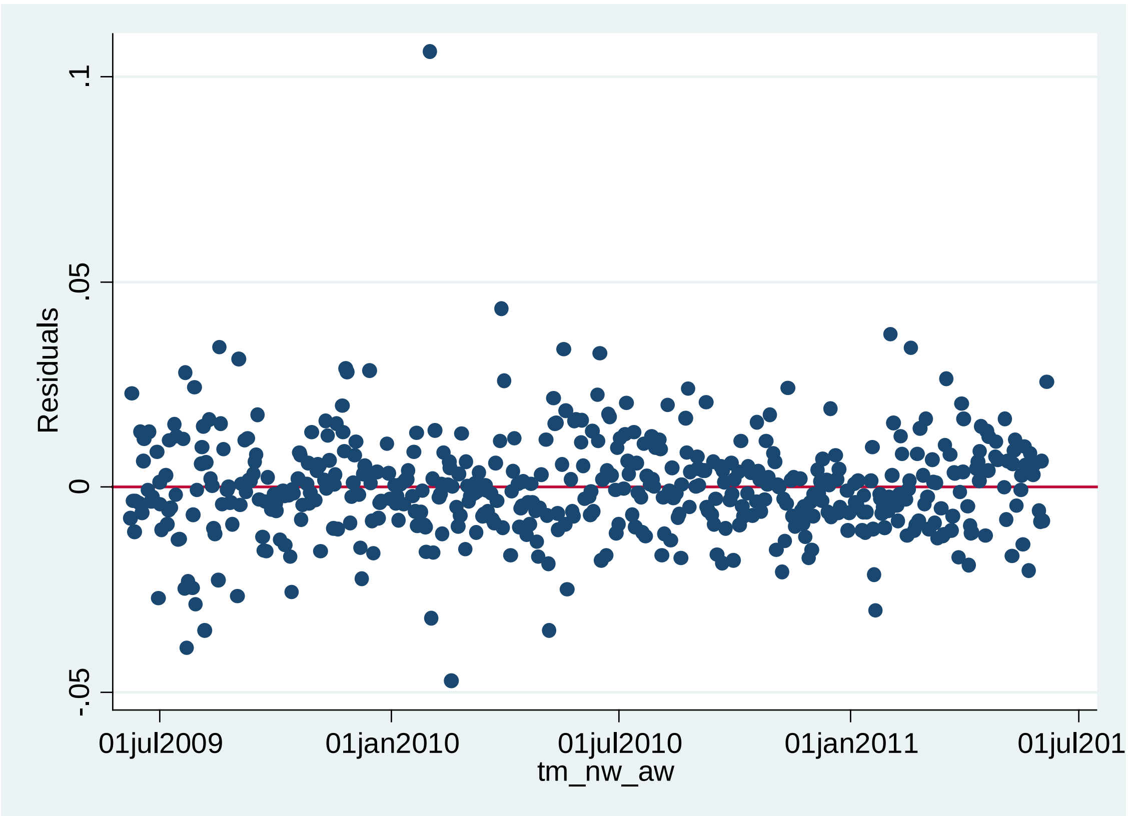


Figure 22: Pennon Group – residuals over time

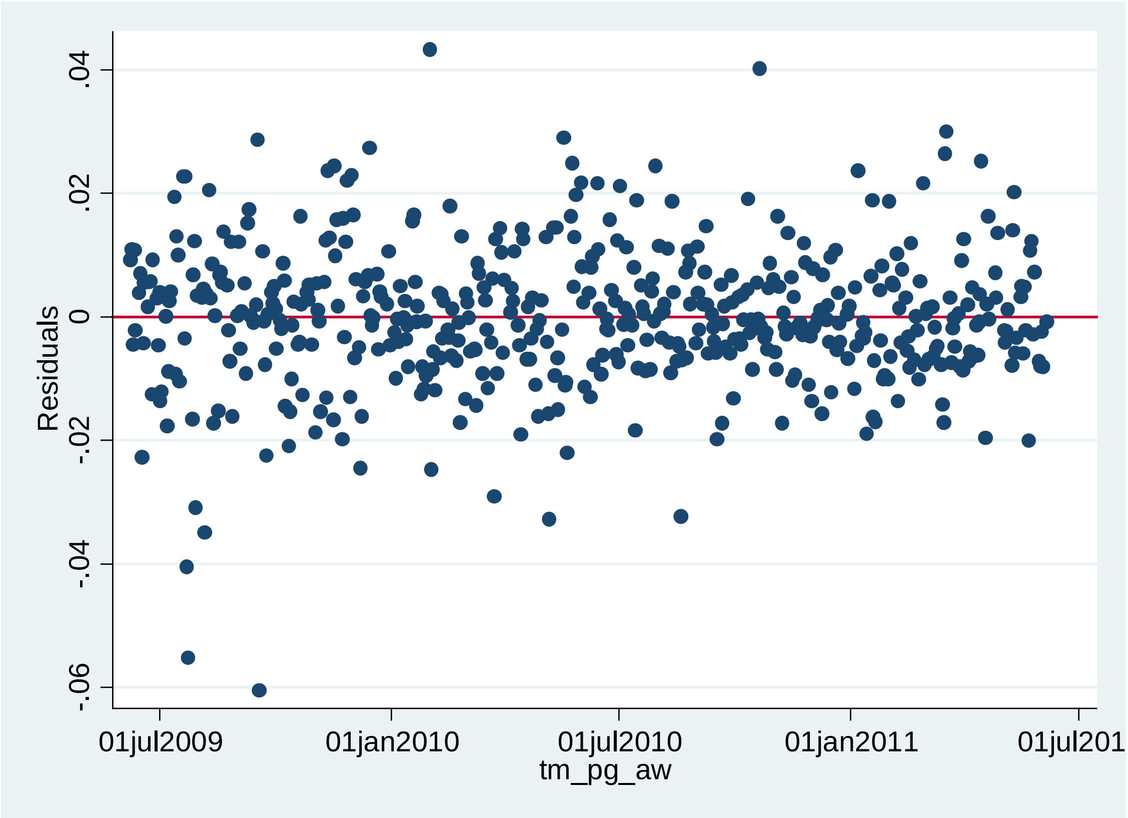


Figure 23: Severn Trent – residuals over time

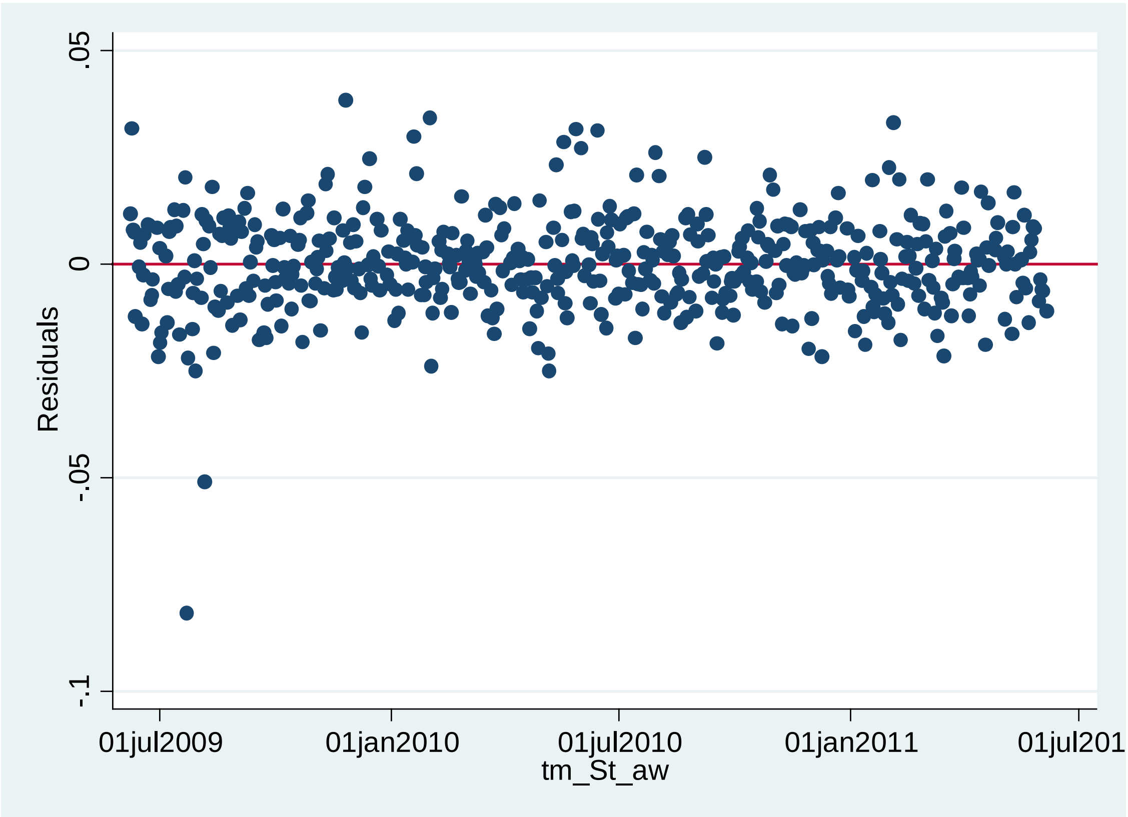
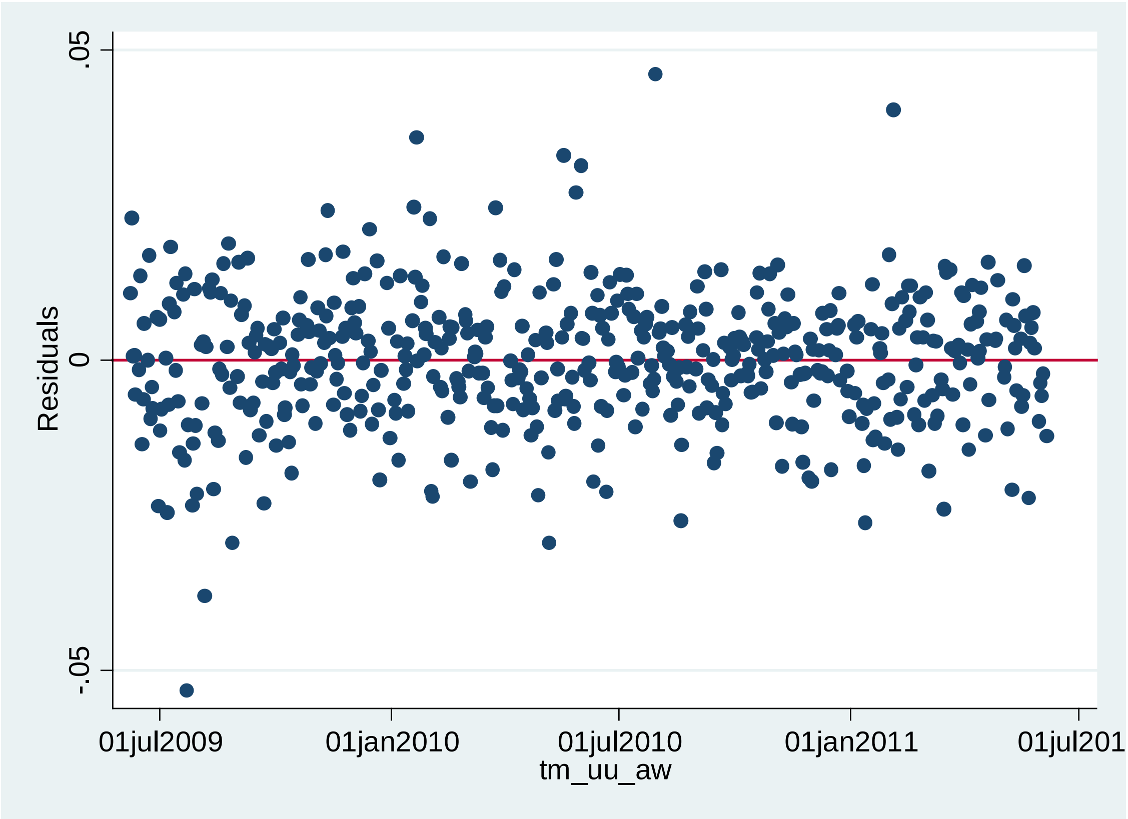


Figure 24: United Utilities – residuals over time



Even though simple inspection suggests that heteroscedasticity cannot be a major concern, we apply a formal test (White's test) to investigate further. Table 4 report the results of the standard diagnostic test. It indicates the absence of heteroscedascity in all of the one- and two-year beta estimates apart from one: the two year estimates only for the National Grid, but not for the other companies.

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	0.61	0.74	No	1.39	0.50	No
All Share	0.79	0.67	No	1.94	0.38	No
UK Utility Peer Group						
National Grid						
All World	0.02	0.99	No	20.64	0.00	Yes
All Share	0.75	0.69	No	0.44	0.80	No
Northumbrian Water						
All World	2.91	0.23	No	1.79	0.41	No
All Share	0.65	0.72	No	1.36	0.51	No
Pennon Group						
All World	0.06	0.97	No	3.95	0.14	No
All Share	0.05	0.98	No	1.07	0.59	No
Severn Trent						
All World	1.56	0.46	No	2.98	0.23	No
All Share	0.30	0.86	No	2.95	0.23	No
United Utilities						
All World	0.11	0.94	No	1.40	0.50	No
All Share	0.21	0.90	No	0.68	0.71	No

Auto-correlation

We also perform a formal test for auto-correlation (the Durbin-Watson test). Perhaps unsurprisingly, this test indicates a degree of autocorrelation in all of the regressions, likely reflecting the reduction in market volatility over time following the credit crisis. 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	1.735	Yes	1.710	Yes
All Share	1.705	Yes	1.690	Yes
UK Utility Peer Group				
National Grid				
All World	1.391	Yes	1.524	Yes
All Share	1.446	Yes	1.511	Yes
Northumbrian Water				
All World	1.404	Yes	1.583	Yes
All Share	1.425	Yes	1.606	Yes
Pennon Group				
All World	1.668	Yes	1.605	Yes
All Share	1.641	Yes	1.634	Yes
Severn Trent				
All World	1.734	Yes	1.722	Yes
All Share	1.743	Yes	1.770	Indecisive
United Utilities				
All World	1.384	Yes	1.556	Yes
All Share	1.341	Yes	1.545	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 and Table 1). 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	0.91	0.11	0.10	0.80	0.09	0.10
All Share	0.94	0.09	0.08	0.91	0.07	0.07
UK Utility Peer Group						
National Grid						
All World	0.57	0.08	0.08	0.45	0.05	0.07
All Share	0.59	0.06	0.07	0.50	0.04	0.05
Northumbrian Water						
All World	0.44	0.09	0.08	0.37	0.06	0.07
All Share	0.51	0.07	0.06	0.46	0.05	0.06
Pennon Group						
All World	0.57	0.08	0.08	0.40	0.06	0.06
All Share	0.61	0.06	0.06	0.48	0.05	0.05
Severn Trent						
All World	0.52	0.08	0.07	0.38	0.06	0.06
All Share	0.55	0.06	0.06	0.42	0.05	0.05
United Utilities						
All World	0.52	0.08	0.08	0.39	0.05	0.06
All Share	0.54	0.06	0.06	0.43	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 25 to Figure 30 show histograms for two-year FTSE All-World regressions.

Figure 25: Studentized residuals - BT

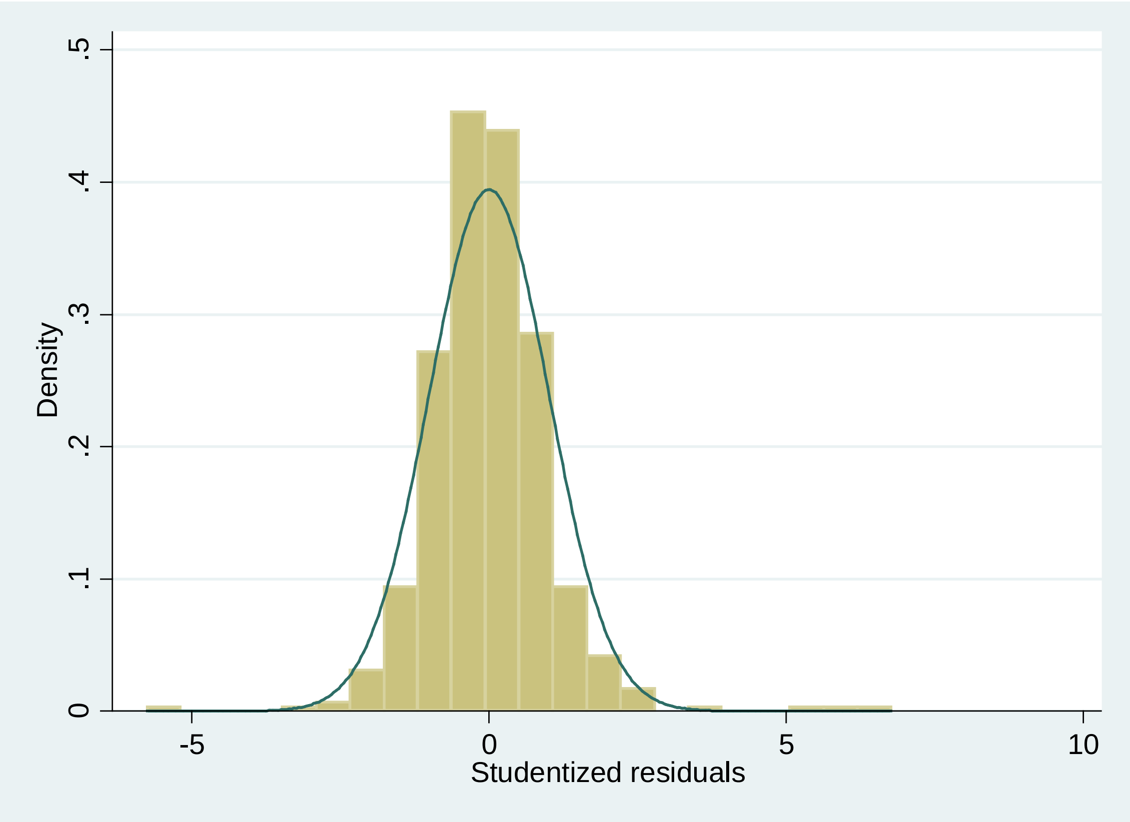


Figure 26: Studentized residuals – National Grid

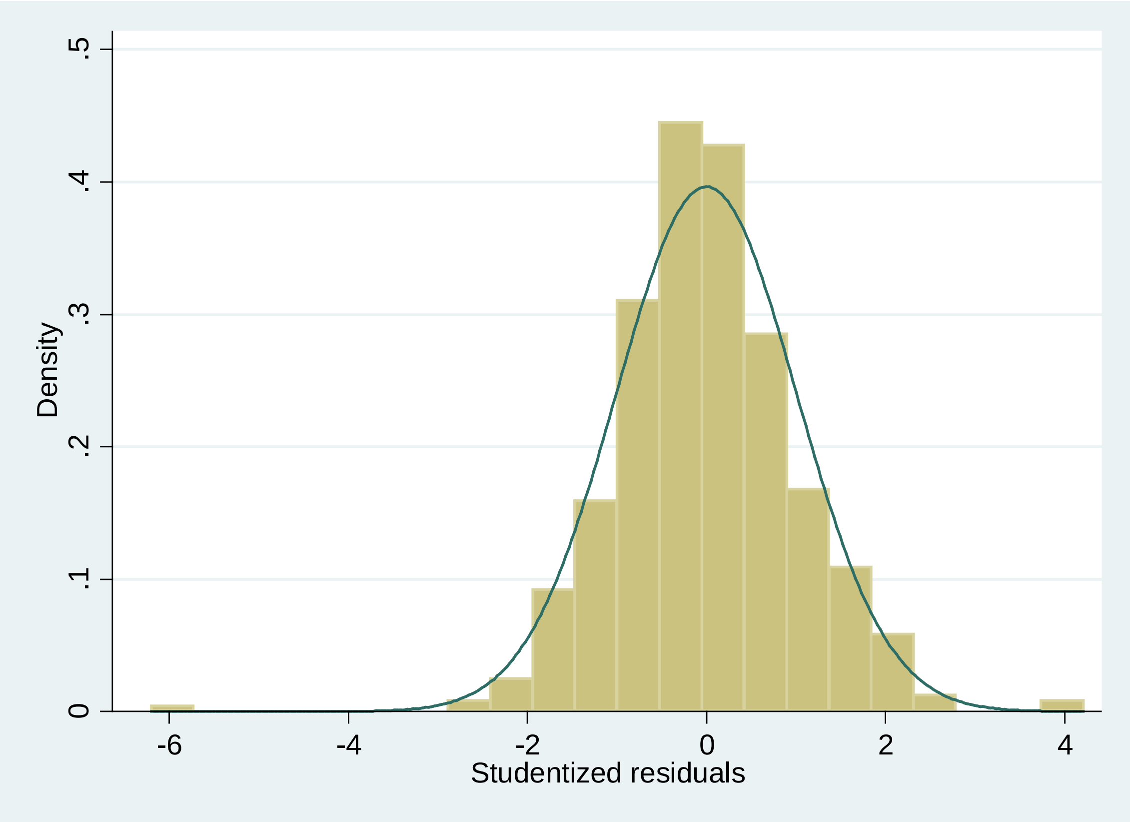


Figure 27: Studentized residuals - Northumbrian Water

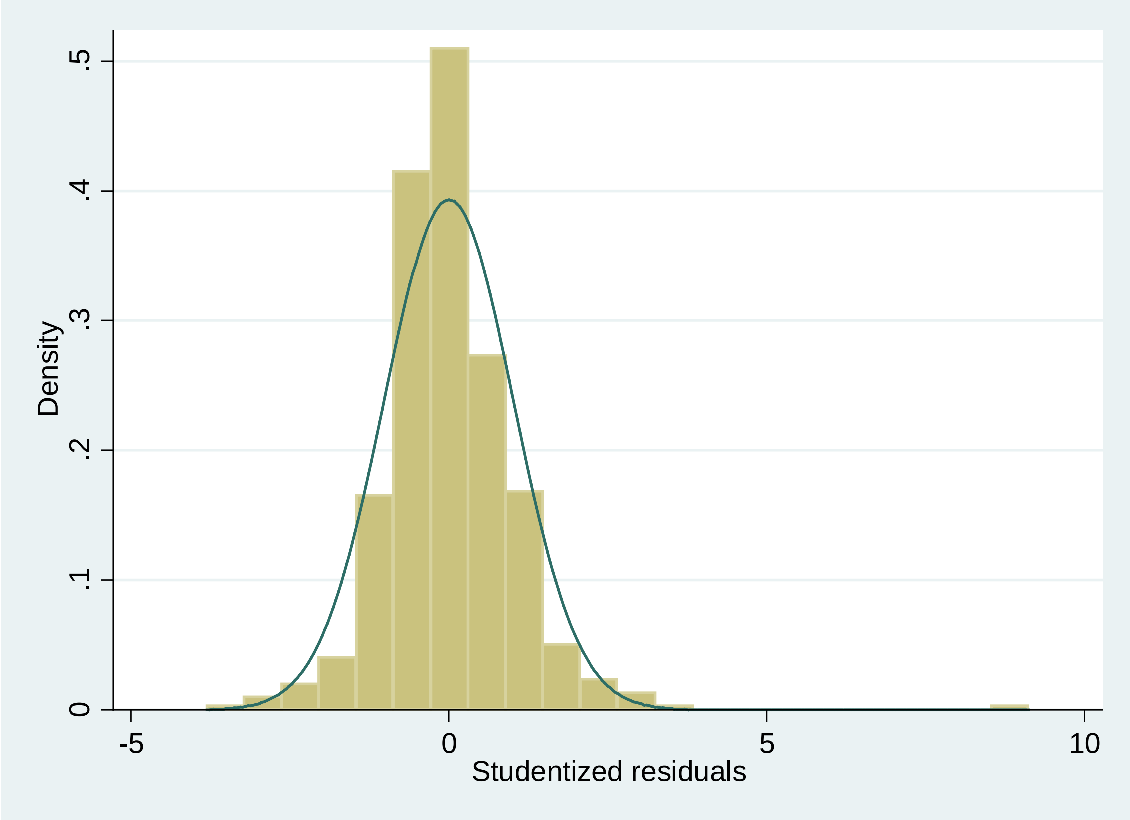


Figure 28: Studentized residuals – Pennon Group

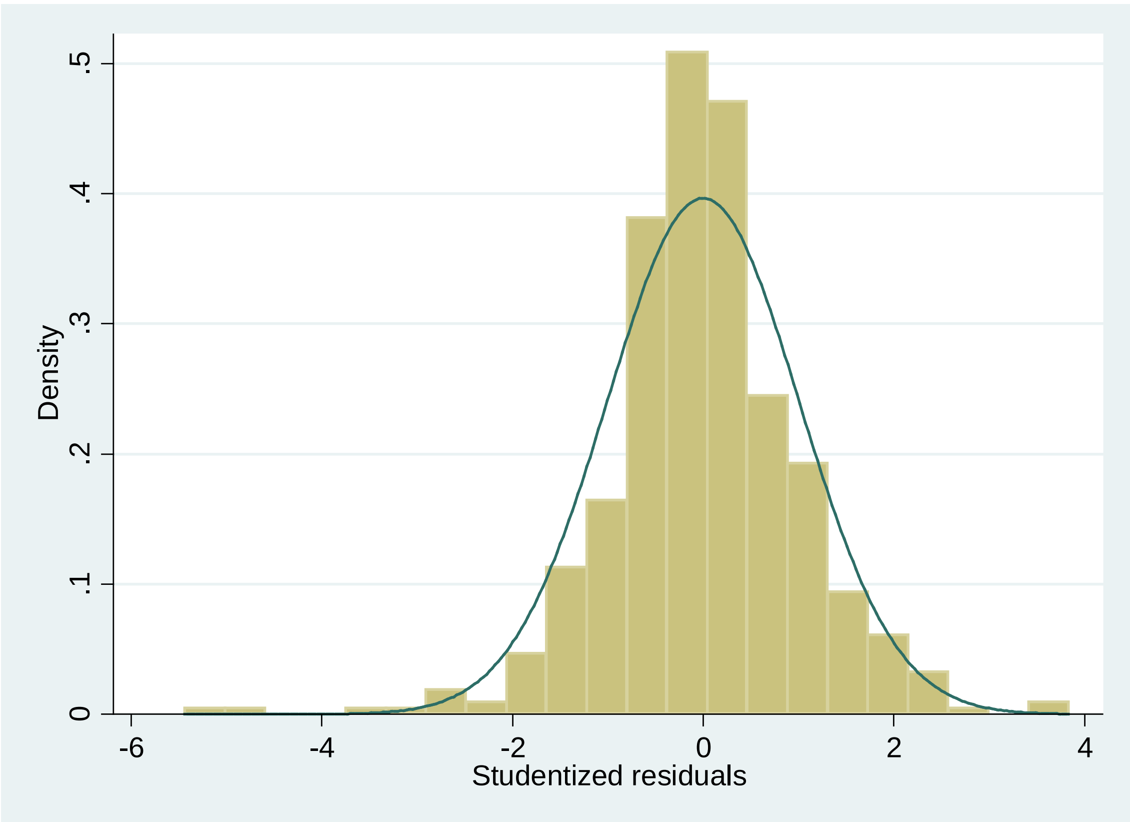


Figure 29: Studentized residuals – Severn Trent

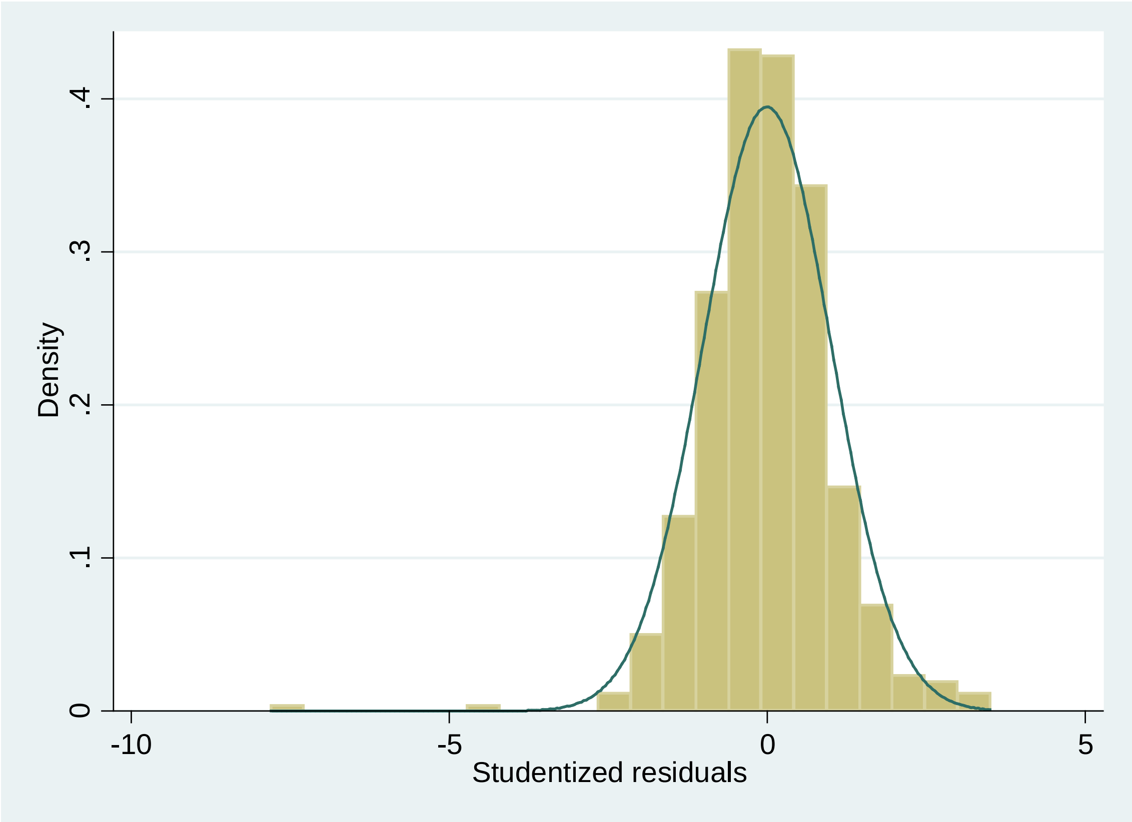
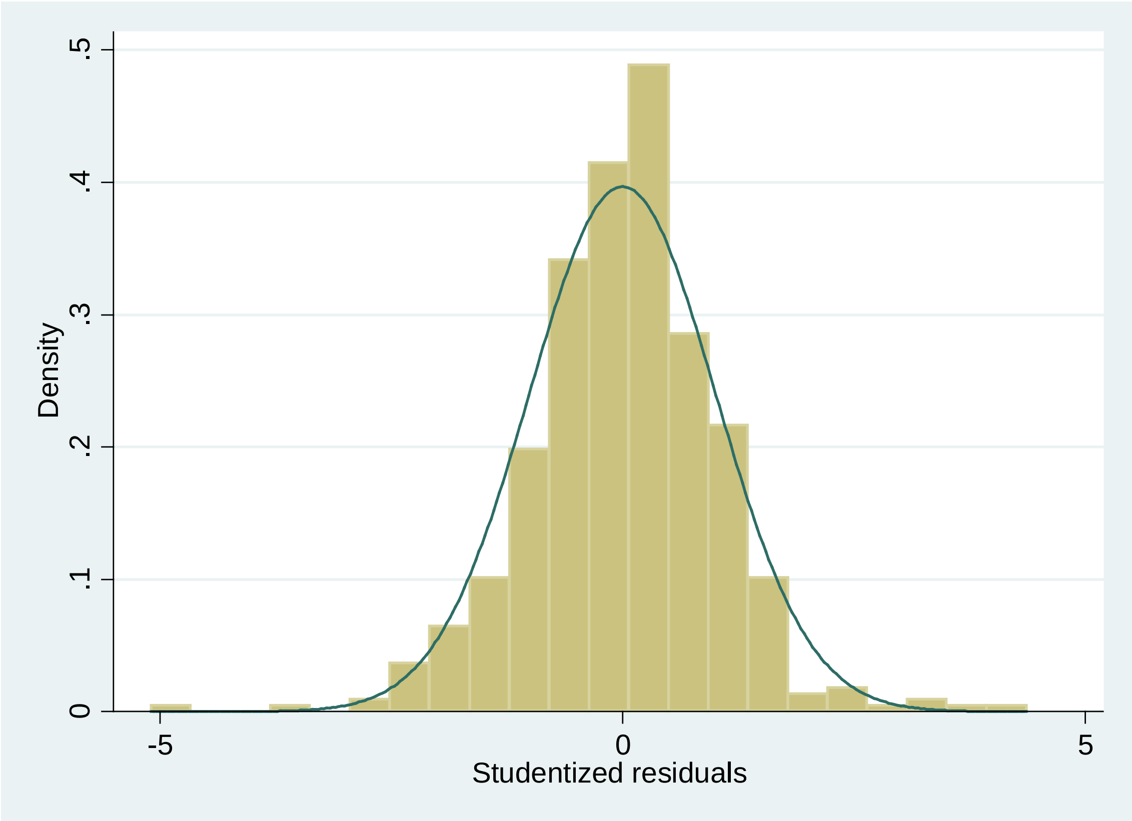


Figure 30: Studentized residuals – United Utilities



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.

Table 7: influential outliers

BT			
All World		**All Share**	
1 Yr	2 Yr	1 Yr	2 Yr
08-Jun-10	16-Jun-09	09-Jun-10	12-Jun-09
09-Jun-10	22-Jun-09	29-Jun-10	16-Jun-09
29-Jun-10	30-Jul-09	02-Aug-10	17-Jun-09
07-Jul-10	02-Sep-09	21-Oct-10	22-Jun-09
22-Jul-10	15-Sep-09	11-Nov-10	15-Jul-09
15-Oct-10	21-Oct-09	26-Nov-10	30-Jul-09
21-Oct-10	23-Oct-09	01-Dec-10	03-Aug-09
11-Nov-10	28-Oct-09	03-Feb-11	14-Oct-09
26-Nov-10	12-Nov-09	08-Mar-11	28-Oct-09
01-Dec-10	30-Nov-09	16-Mar-11	11-Feb-10
	11-Feb-10	04-May-11	26-Feb-10
	01-Mar-10		07-May-10
	27-Apr-10		10-May-10
	07-May-10		13-May-10
	10-May-10		25-May-10
	11-May-10		29-Jun-10
	13-May-10		02-Aug-10
	20-May-10		11-Nov-10
	25-May-10		26-Nov-10
	27-May-10		01-Dec-10
	01-Jun-10		
	09-Jun-10		
	29-Jun-10		
	21-Oct-10		
	11-Nov-10		

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 31 to Figure 36 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	0.91	0.97	0.91	10	0.80	0.83	0.80	25
All Share	0.94	0.99	0.94	11	0.91	0.90	0.86	20
UK Utility Peer Group								
National Grid								
All World	0.57	0.58	0.57	18	0.45	0.43	0.45	25
All Share	0.59	0.61	0.59	17	0.50	0.49	0.50	25
Northumbrian Water								
All World	0.44	0.46	0.44	14	0.37	0.43	0.37	29
All Share	0.51	0.53	0.51	14	0.46	0.51	0.46	25
Pennon Group								
All World	0.57	0.55	0.57	15	0.40	0.45	0.40	27
All Share	0.61	0.61	0.61	15	0.48	0.55	0.48	28
Severn Trent								
All World	0.52	0.54	0.52	11	0.38	0.46	0.38	25
All Share	0.55	0.56	0.55	14	0.42	0.49	0.42	22
United Utilities								
All World	0.52	0.56	0.52	13	0.39	0.47	0.39	28
All Share	0.54	0.57	0.54	12	0.43	0.49	0.43	22

Figure 31: One-year beta against FTSE All-Share – BT

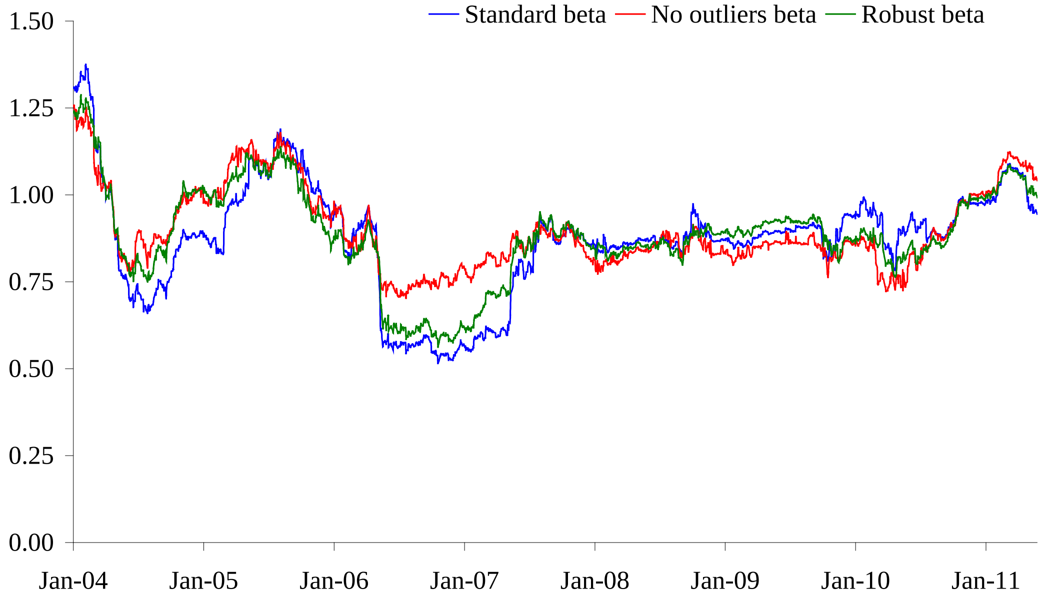


Figure 32: One-year beta against FTSE All-Share – National Grid

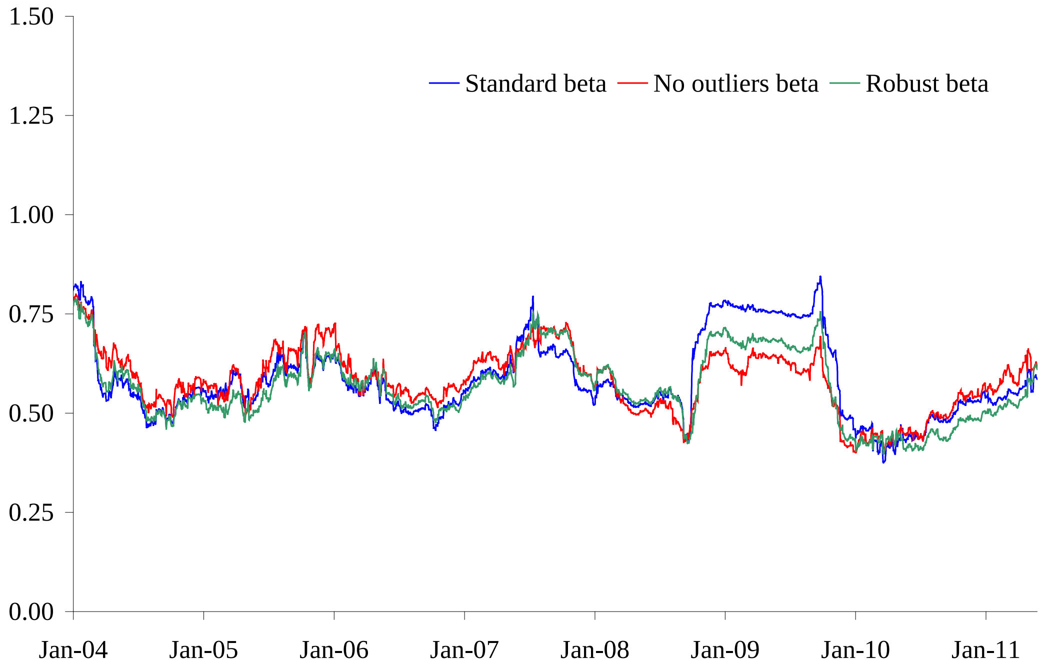


Figure 33: One-year beta against FTSE All-Share – Northumbrian Water

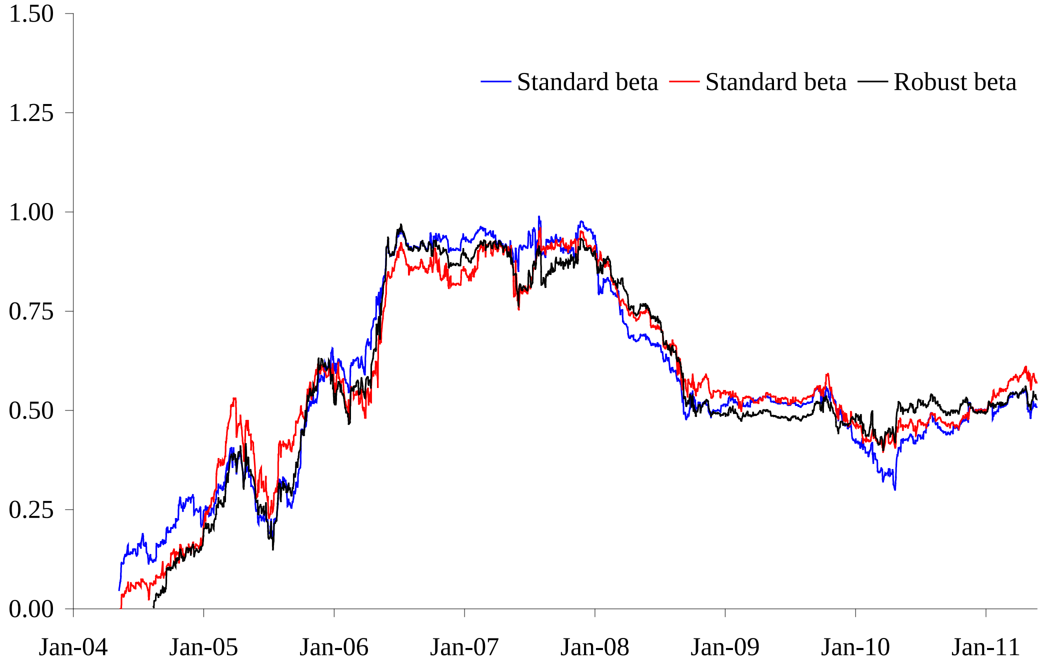


Figure 34: One-year beta against FTSE All-Share – Pennon Group

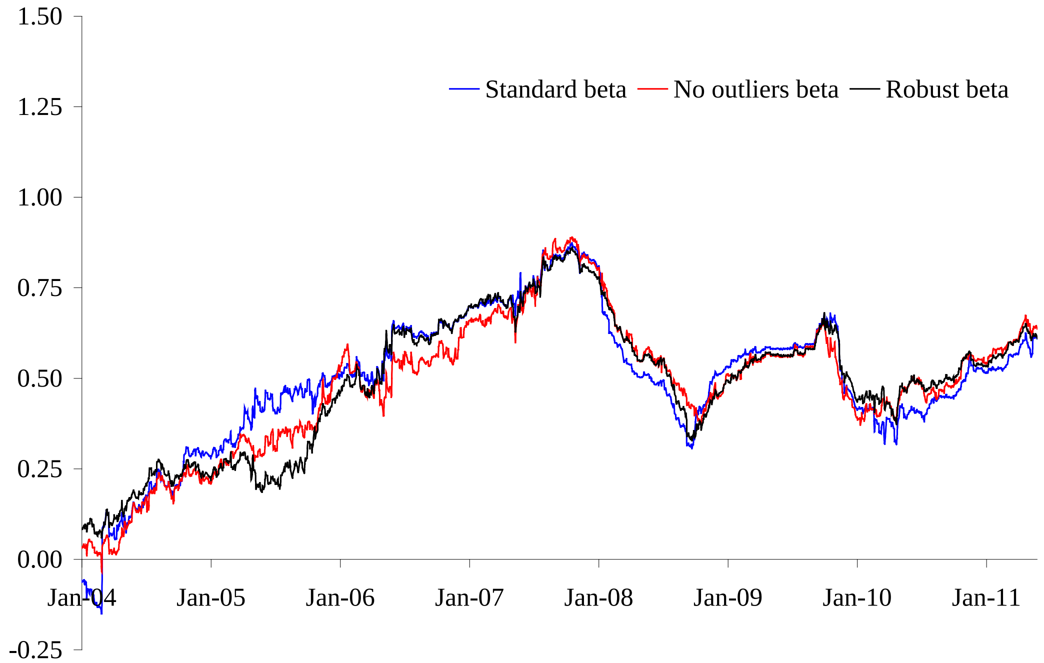


Figure 35: One-year beta against FTSE All-Share – Severn Trent

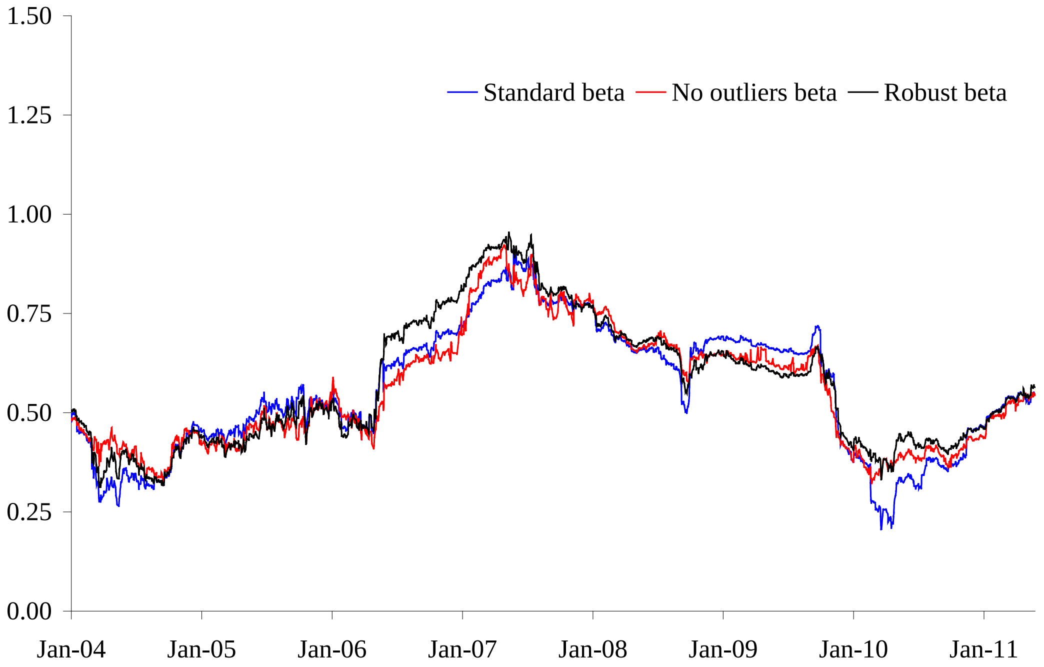


Figure 36: One-year beta against FTSE All-Share – United Utilities