

ESTIMATE OF BT'S EQUITY BETA

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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 leased lines services 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 four other publicly traded UK utilities: National Grid (the gas and electricity transmission system operator) and three water utilities (United Utilities, Severn Trent, and Pannon Group). Our previous update included Northumbrian Water Group in the UK utilities peer group, but it has since been purchased by Cheung Kong Infrastructure Holdings. All of the companies in the UK utility peer group provide essential services and are subject to regulated price-caps. 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 four 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). Two 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.³

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 32% of BT's 2011 revenues and 10% of 2011 EBITDA.⁴ 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

¹ We last provided an update of BT's equity beta in July 2011. See *Estimate of BT's Equity Beta* (July 2011), 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.

³ We included Qwest in our US telecom peer group in our last update. Qwest was purchased by CenturyLink at the end of 2010.

⁴ See BT Group plc. 2011 Annual Report, p. 106.

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. For example, developing wireless technology may supplant the need for local loop services. Although facing different regulatory regimes, the US peer group at least reflects similar risks with the interaction with wireless. 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 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 Openreach's allowed revenues.

In this report, we adopt the same methodology as in other previous engagements for Ofcom.⁵ 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 December 10, 2012.

Previous work for Ofcom examined beta estimation methods.⁶ 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.

⁵ 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).

⁶ 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 December 10, 2012.

Table 1: Up-to-date beta estimates⁷

	1 Year				2 Year			
	Beta	SE	Low	High	Beta	SE	Low	High
<i>BT</i>								
All World	1.11	0.12	0.87	1.35	1.03	0.07	0.90	1.16
All Share	0.99	0.08	0.83	1.15	1.01	0.05	0.92	1.11
<i>UK Utility Peer Group</i>								
<i>National Grid</i>								
All World	0.44	0.08	0.28	0.59	0.40	0.05	0.31	0.49
All Share	0.38	0.06	0.27	0.49	0.42	0.04	0.35	0.49
<i>Pennon Group</i>								
All World	0.37	0.11	0.16	0.58	0.47	0.05	0.37	0.58
All Share	0.45	0.07	0.31	0.60	0.51	0.04	0.43	0.60
<i>Severn Trent</i>								
All World	0.35	0.11	0.15	0.56	0.48	0.05	0.38	0.59
All Share	0.44	0.07	0.30	0.58	0.51	0.04	0.43	0.59
<i>United Utilities</i>								
All World	0.29	0.10	0.10	0.48	0.45	0.05	0.35	0.55
All Share	0.37	0.07	0.24	0.51	0.47	0.04	0.39	0.54
<i>Peer Group Average</i>								
All World	0.36				0.45			
All Share	0.41				0.48			

The most recent data indicate little change in the level of BT's equity beta since our last update. Against the FTSE All-Share, we estimate an up-to-date one-year equity beta of 0.99, compared with our estimate of 0.94 as of June 2011. We estimate an up-to-date two-year equity beta of 1.01, compared with our estimate of 0.91 as of June 2011. The changes in the level of the raw equity betas are within the range of statistical error. BT equity betas against the FTSE All-World have also seen little change since June 2011.

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 both the one-year and two-year BT equity betas over the past several years, despite the spike in price volatility at the end of 2008 and the first part

⁷ 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.

of 2009. There has been a notable convergence between the one-year and two-year betas since 2009. The one-year beta has varied between a low of 0.78 and a high of 1.09, while the two year estimate declined to a low of 0.84 in the first half of 2010 before climbing to 1.05 by the end of 2011.

Figure 1: BT rolling betas

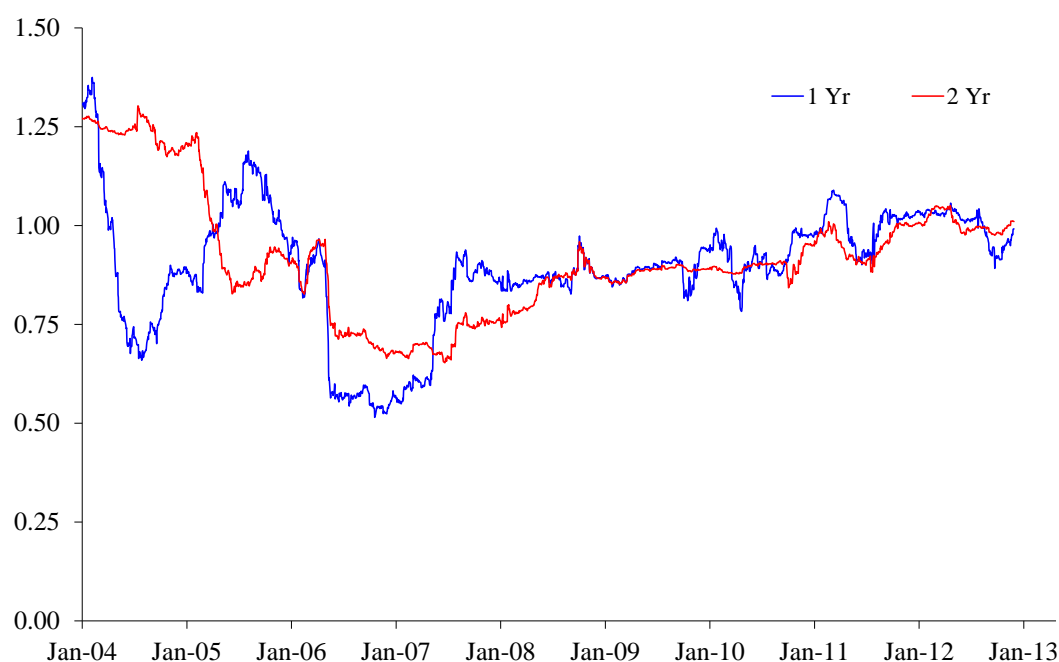


Table 1 confirms that BT's equity beta comes in higher than the rest of the UK utility reference sample. Both BT's one- and two-year equity betas are now double the average of the other three UK utilities (0.99 vs 0.44 for the one-year, 1.01 vs 0.48 for the two-year). The gap between BT and the other utilities has widened ever so slightly over the past two years. While both BT's one-year and two-year equity betas have remained stable, only the two-year estimates for the other utilities have displayed some degree of stability more recently. The effect of the credit crisis is apparent in the utility peer group estimates.

Figure 2 to Figure 5 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 their one-year equity betas 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 2010 and the first half of 2011, the one-year betas trend upwards towards previous levels, before falling back to the immediately post-crisis levels by the middle of this year.

Interestingly, the two-year beta estimates for the UK utility peer group all display a step rise at the end of 2008 immediately following the collapse of Lehman Brothers, and a corresponding step decline at the end of 2010 as data from autumn 2008 drops out of the

data window. Since then, the two-year estimates for the UK utility peer group have remained remarkably stable. National Grid's two-year estimate has varied between a low of 0.42 and a high of 0.53; Pennon Group's between 0.42 and 0.55; Severn Trent's between 0.37 and 0.52; and United Utilities' between 0.41 and 0.49.

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

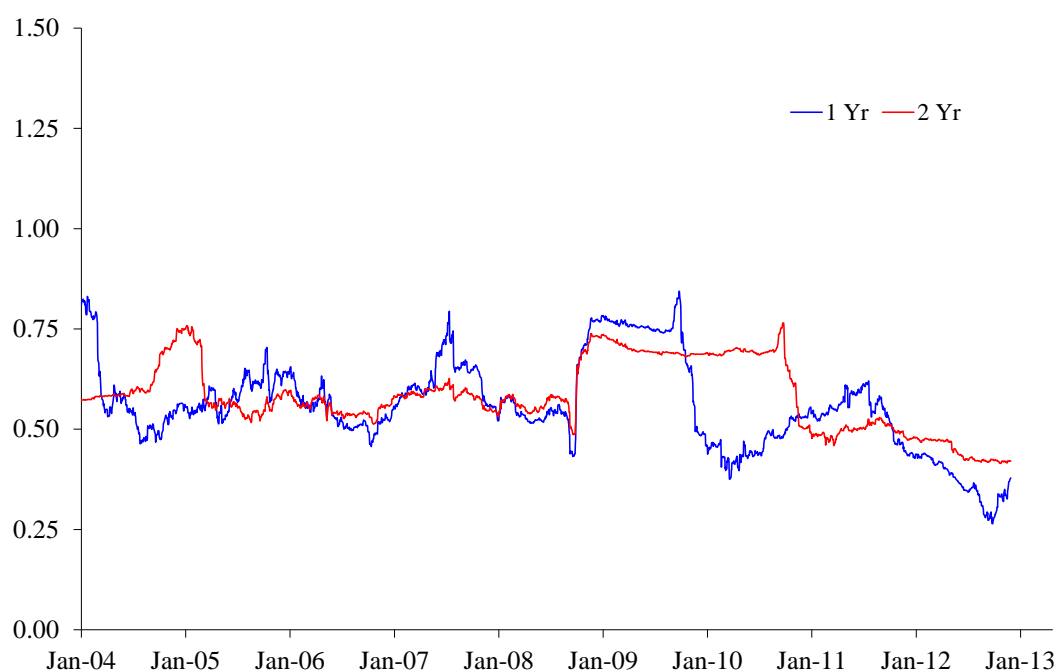


Figure 3: Pennon Group rolling betas

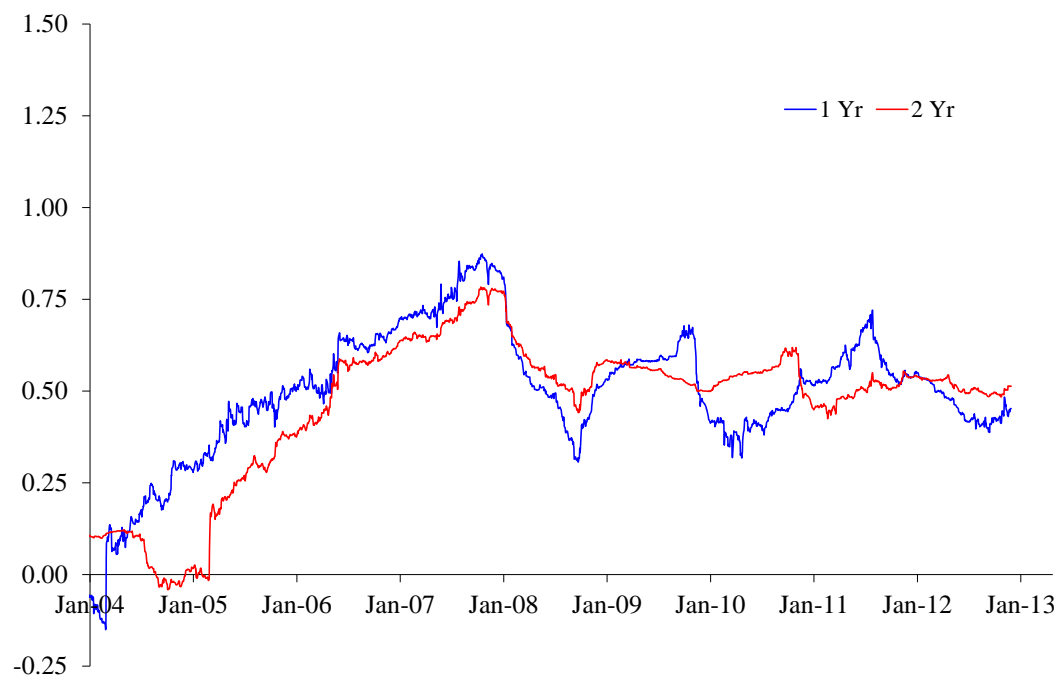


Figure 4: Severn Trent rolling betas

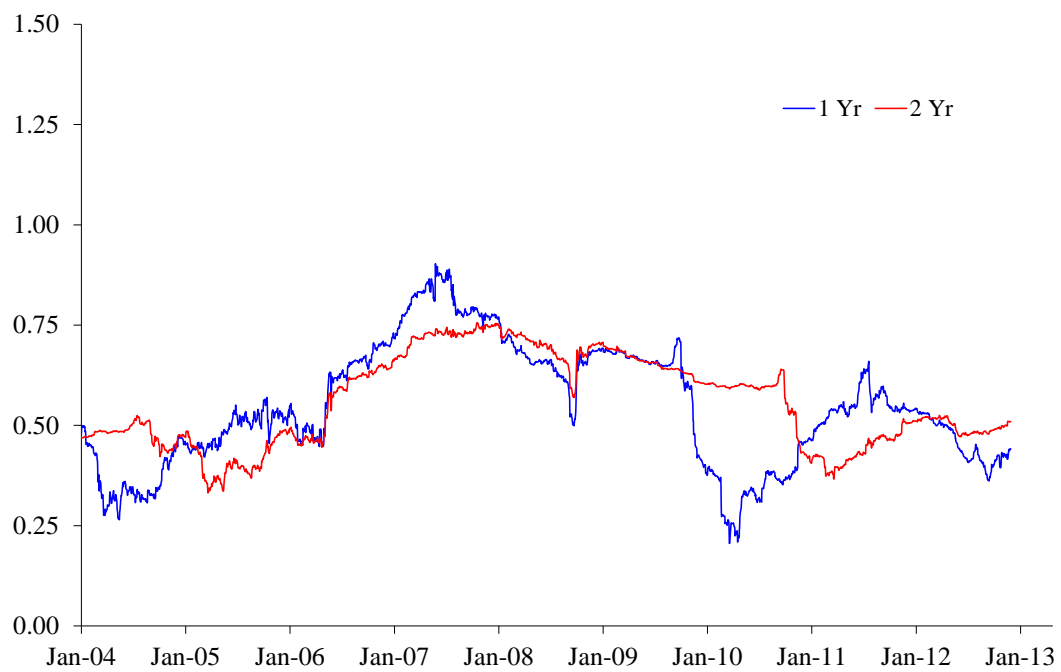
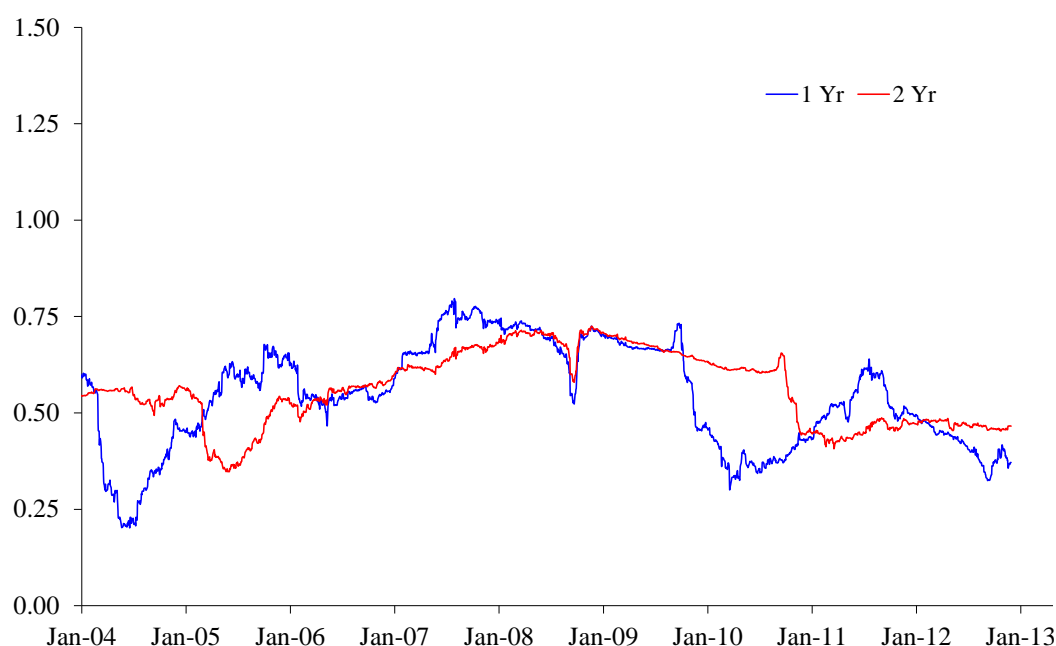


Figure 5: United Utilities rolling betas



2.2 Financial leverage

Equity risk reflects the combination of underlying business risk (principally to do with the cyclicity 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 four 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 four 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 could have diverged significantly from face value, most likely 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%.⁸

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 stability of the market-to-book ratios for high grade utility debt.

We compute financial leverage in the same way as in our previous updates, with reference to the face value of outstanding debt⁹ and ignoring BT's pension fund deficit. The use of the face value of outstanding debt finds support in a leading corporate finance textbook: first compute working capital (current assets less current liabilities) for each company. If working capital is positive, analysts should zero out short-term debt and estimate financial leverage with reference to long-term debt only. But if working capital is negative, analysts should estimate financial leverage with reference to the sum of long-term plus short-term debt. Since BT's current liabilities consistently exceed its current assets (including cash), we end-up using the face value of both long-term and short-term debt in the leverage computation.¹⁰ We ignore BT's pension fund deficit in part because the potential impact on the beta is not at all obvious.

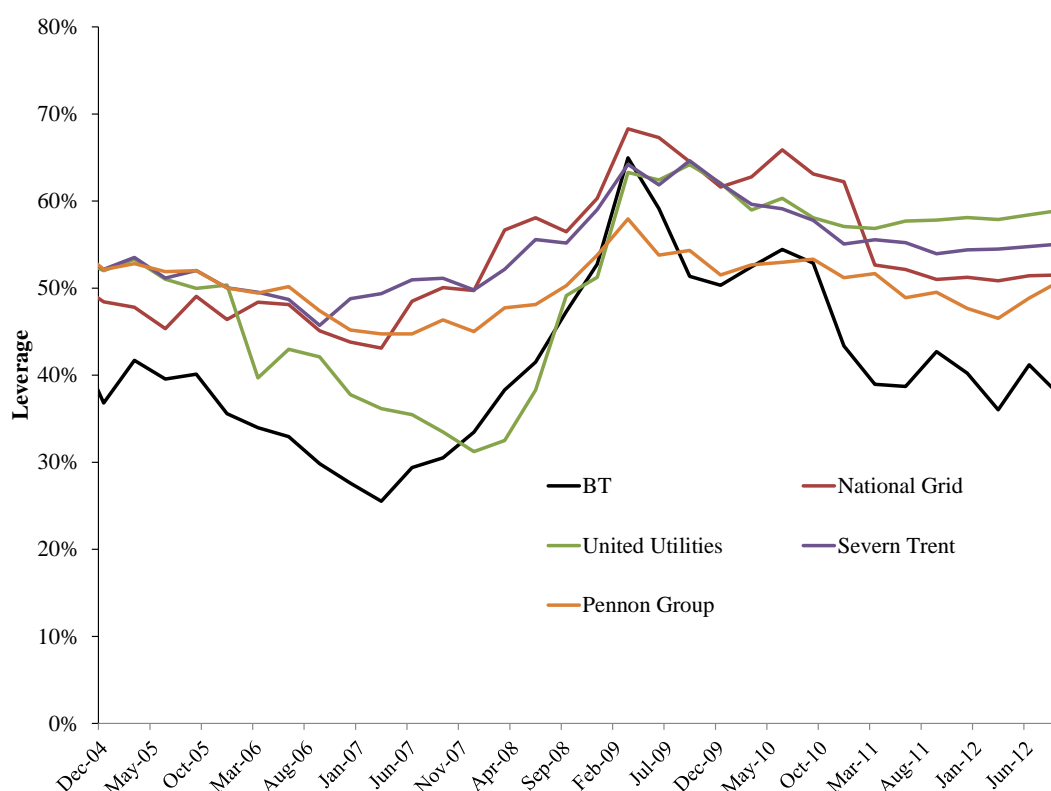
Figure 6 plots our resulting estimates of financial leverage for the UK utility reference sample.

⁸ 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 1.01 assuming gearing of 40% and a debt beta of 0.15, we would derive an asset beta of 0.67. Assuming gearing of 37.5%, we would derive an asset beta of 0.6875, or only 3% higher than that derived using the book value of debt.

⁹ As opposed to "net debt", which equals the face value of short and long term financial debt less cash.

¹⁰ See Brealey, Richard A, Myers, Stewart C, and Allen, Franklin, *Principles of Corporate Finance*, Ninth Edition, McGraw Hill, (2006), p. 539.

Figure 6: 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. Over the past two years, both BT's share price and its stock of outstanding debt have remained relatively steady. Of the other UK utility peer group, only United Utilities witnessed a similar swing in leverage during the recent measurement period. Following the recovery of BT's share price, BT's financial leverage has returned to a level somewhat below the UK utility peer group.

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.¹¹ 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

¹¹ We use a standard relevering formula (see *Principles of Corporate Finance* (8th edition), Brealey Myers and Allen, p. 518).

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 focussing on two-year betas, we estimate average leverage across the two-year measurement window. Figure 7 and Figure 8 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 for the period after pre-credit crisis data has dropped out of the data window. A further figure compares one- and two-year asset betas for BT. BT's asset beta has now returned to the peak witnessed prior to the collapse of Lehman in 2008.

Table 2: “Asset” betas

	1 Year		2 Year	
	$\beta_{debt=0}$	$\beta_{debt=0.15}$	$\beta_{debt=0}$	$\beta_{debt=0.15}$
<i>BT</i>				
All World	0.65	0.71	0.62	0.68
All Share	0.58	0.64	0.61	0.67
<i>UK Utility Peer Group</i>				
<i>National Grid</i>				
All World	0.20	0.28	0.20	0.27
All Share	0.17	0.26	0.21	0.28
<i>Pennon Group</i>				
All World	0.19	0.26	0.24	0.32
All Share	0.23	0.30	0.26	0.34
<i>Severn Trent</i>				
All World	0.16	0.24	0.22	0.30
All Share	0.20	0.28	0.23	0.31
<i>United Utilities</i>				
All World	0.12	0.21	0.19	0.27
All Share	0.16	0.24	0.19	0.28
<i>Peer Group Average</i>				
All World	0.17	0.20	0.21	0.29
All Share	0.19	0.22	0.22	0.30

Figure 7: One-year asset betas - FTSE All-Share

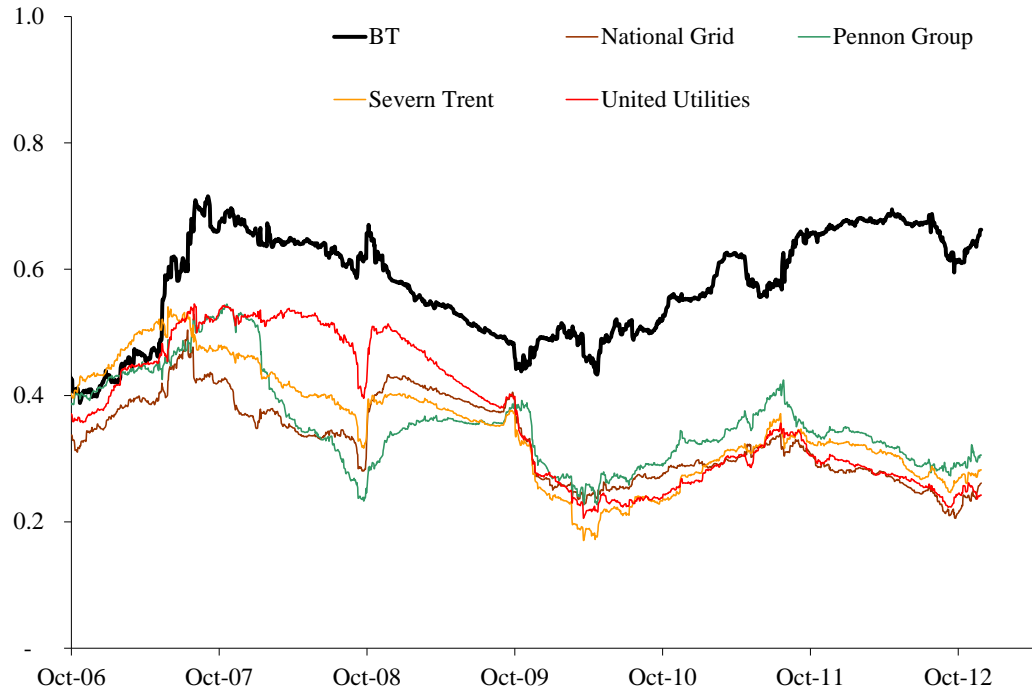


Figure 8: Two-year asset betas - FTSE All-Share

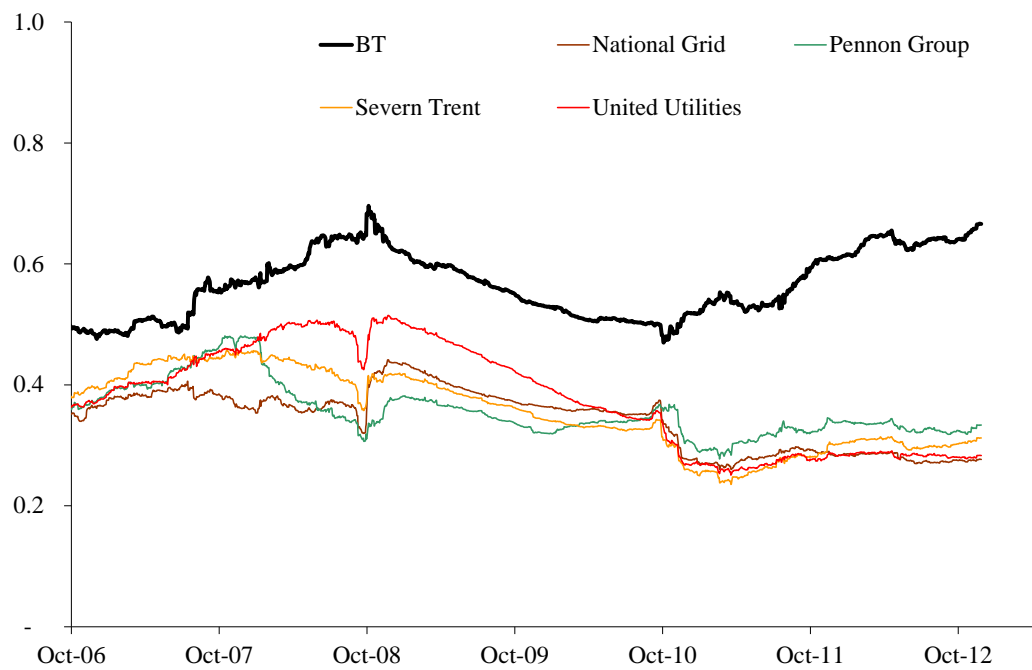
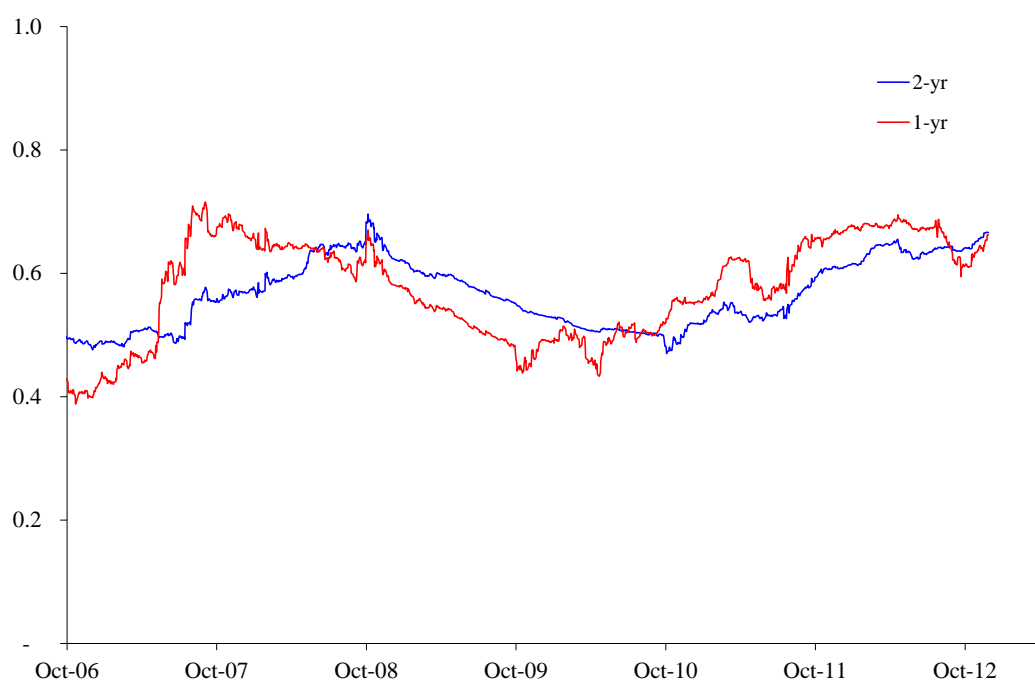


Figure 9: One and two year asset betas – BT vs FTSE All-Share



2.3 US Telecoms

In addition to the UK utility reference sample, we examined data for four US telecommunications companies¹²: Frontier, Windstream, AT&T and Verizon. Two of the companies are pure-play wireline (Frontier 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.¹³ 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 standard techniques, we estimated asset betas for each of the four US telecoms companies. Figure 10 to Figure 11 plot the development of the asset betas over time. Over most of the period, asset betas for the two pure-play US wireline stocks against the S&P 500 come in below the level for BT against the FTSE All-Share. Since 2010, the gap between BT and the remaining two pure-play wireline stocks has grown. While the US pure-play wireline asset betas remained relatively steady since 2009, the BT betas have displayed a slight increase.

¹² Our previous update also examined the stock performance of Qwest. Qwest was bought by CenturyLink in Apr-11. We stop tracking the Qwest 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.

¹³ In 2011, AT&T obtained roughly 47% of revenues from wireline activities, compared with 37% for Verizon. *See* AT&T 2011 Annual Report, p. 33; Verizon 2011 Annual Report, p. 29.

The BT asset beta also has grown relative to those of the two integrated large cap US telecoms companies: AT&T and Verizon. The divergence begins to appear in both the one-year and two-year betas at roughly the start of 2010. The divergence seems mostly complete by the end of 2011, 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 more risky than AT&T or Verizon, while they have viewed AT&T and Verizon about or perhaps just slightly more risky than the pure-play wireline stocks.

Figure 10: One-year asset betas of US sample

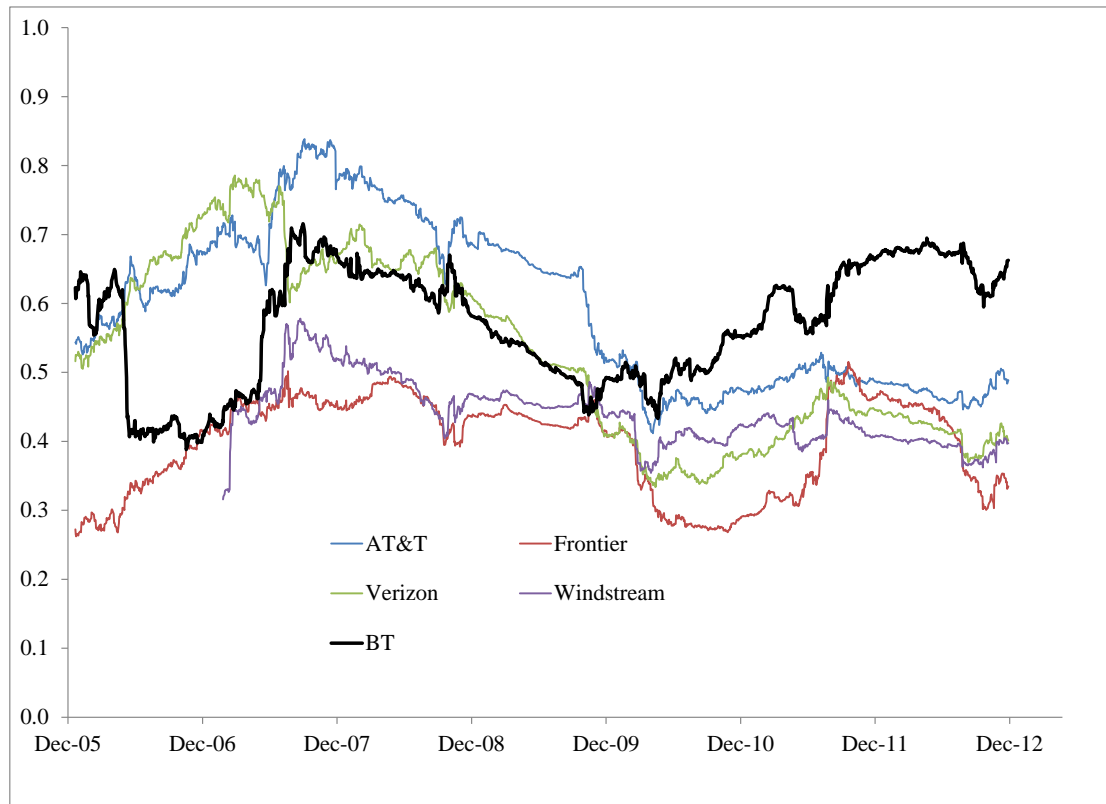
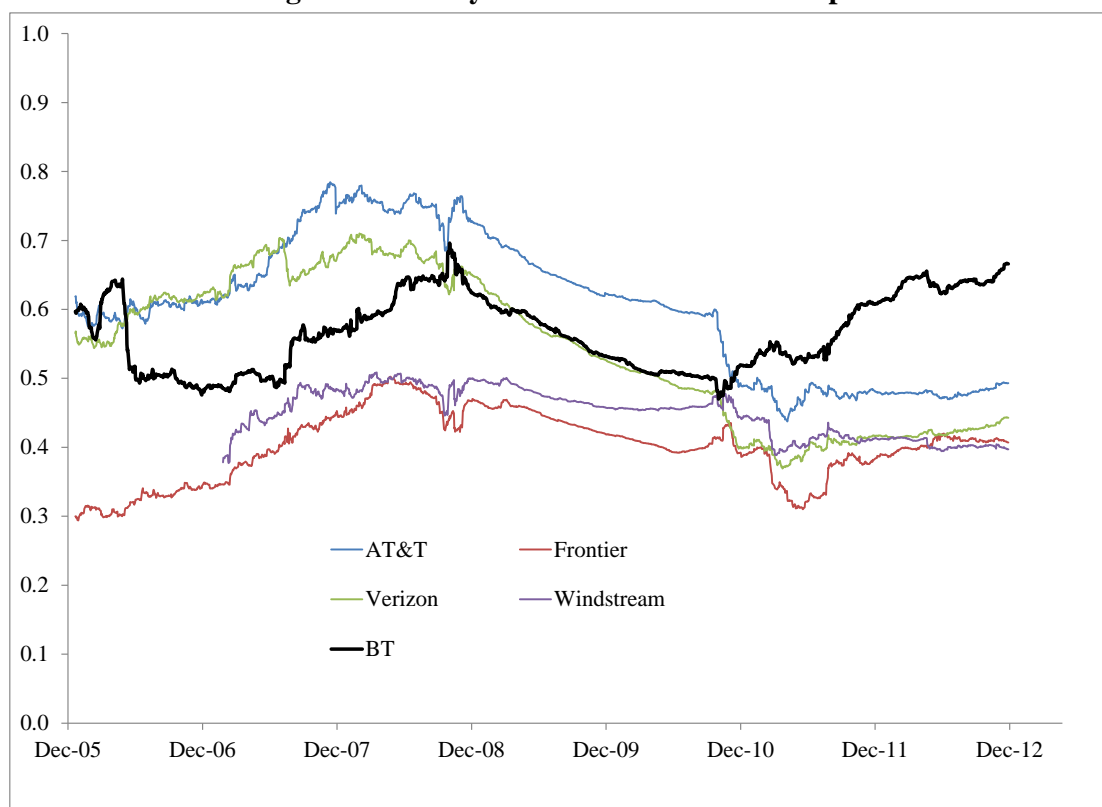


Figure 11: Two-year asset betas for US sample



2.4 Conclusions

In our last update, we remained concerned about the large swing in BT's financial leverage over the past few years and its implications for our beta calculations. We have no such concerns this time round. BT's financial leverage has remained steady throughout the two year data window.

Based on our regressions, the last two years of data generates an estimate for the equity beta of BT is 1.01 against the FTSE All-Share. This estimate corresponds with average leverage during the two-year measurement window of 40%, and implies an asset beta for BT of between 0.61 and 0.67 depending on our assumption with respect to debt beta. The last year of data generates almost identical estimates: an equity beta of 0.99 against the FTSE All-Share, corresponding with average leverage of just over 41%. The last year of data implies an asset beta of 0.58 to 0.64, again dependent on our debt beta assumption. 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 remains 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 increase in beta with the onset of the credit crisis and then a sharp decrease following the elimination of pre-crisis data from the analysis. BT's beta displays no such drop following the elimination of pre-crisis data. If we attribute such recent movements in the betas to a change in perceptions following 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" following

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 utilities, but slightly lower than those for BT.

We normally recommend a range of +/- approximately two standard deviations around our mid-point figures: 0.09 for the last year of data, and 0.06 for the last two-years. This implies a range for the one-year beta against the FTSE All-Share of 0.82 to 1.16, translating into a range in asset beta of between 0.48 and 0.74 (incorporating the measurement error on the equity beta and depending on whether the debt beta is assumed at zero or 0.15). The equivalent range for the two-year beta against the FTSE All-Share is 0.89 to 1.13, translating into a range in asset beta of between 0.54 and 0.74 (again incorporating the measurement error on the equity beta and depending on whether the debt beta is assumed at zero or 0.15).

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.¹⁴ We perform a number of statistical tests to check for potential problems in this case. Below we report the results of our statistical tests for BT and the UK utility peer group. We performed exactly the same tests for the betas computed above for the four US telecom companies. We confirm the statistical robustness of the US company betas presented above.

3.1 Dimson adjustment

To test for possible bias relating to trading illiquidity and to assess if time differences¹⁵ 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 four other UK utilities, four out of twenty lag terms were significantly different from zero (three of four related to the All-World, only one to the All-Share). The lead term was never significantly different from zero. In only one case out of twenty separate beta estimates were the Dimson adjustments overall significantly different from zero: the two-year beta for BT against the FTSE All-World.¹⁶

¹⁴ See *Issues in beta estimation for UK mobile operators*, July 2002.

¹⁵ 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.

¹⁶ We might expect a false positive once in every twenty beta estimates, given the extent of the standard errors.

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

	1 Yr				2 Yr			
	Beta	Dimson Beta	Dimson SE	Significance	Beta	Dimson Beta	Dimson SE	Significance
<i>BT</i>								
All World	1.11	0.95	0.20	Neither lag nor lead	1.03	1.24	0.10	Only Lag
All Share	0.99	0.78	0.15	Neither lag nor lead	1.01	1.07	0.08	Only Lag
<i>UK Utility Peer Group</i>								
<i>National Grid</i>								
All World	0.44	0.36	0.13	Only Lag	0.40	0.44	0.07	Neither lag nor lead
All Share	0.38	0.41	0.11	Neither lag nor lead	0.42	0.45	0.06	Neither lag nor lead
<i>Pennon Group</i>								
All World	0.37	0.27	0.17	Neither lag nor lead	0.47	0.53	0.08	Neither lag nor lead
All Share	0.45	0.50	0.14	Neither lag nor lead	0.51	0.56	0.07	Neither lag nor lead
<i>Severn Trent</i>								
All World	0.35	0.29	0.17	Neither lag nor lead	0.48	0.55	0.08	Neither lag nor lead
All Share	0.44	0.41	0.14	Neither lag nor lead	0.51	0.55	0.07	Neither lag nor lead
<i>United Utilities</i>								
All World	0.29	0.08	0.16	Only Lag	0.45	0.46	0.08	Neither lag nor lead
All Share	0.37	0.24	0.13	Neither lag nor lead	0.47	0.47	0.07	Neither lag nor lead
<i>Peer Group Average</i>								
All World	0.36	0.25			0.45	0.50		
All Share	0.41	0.39			0.48	0.51		

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 12 to Figure 16 show scatter plots of the residuals against the returns predicted by the regression, for two-year regressions against the FTSE All-Share. 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 12: BT - residuals against fitted values

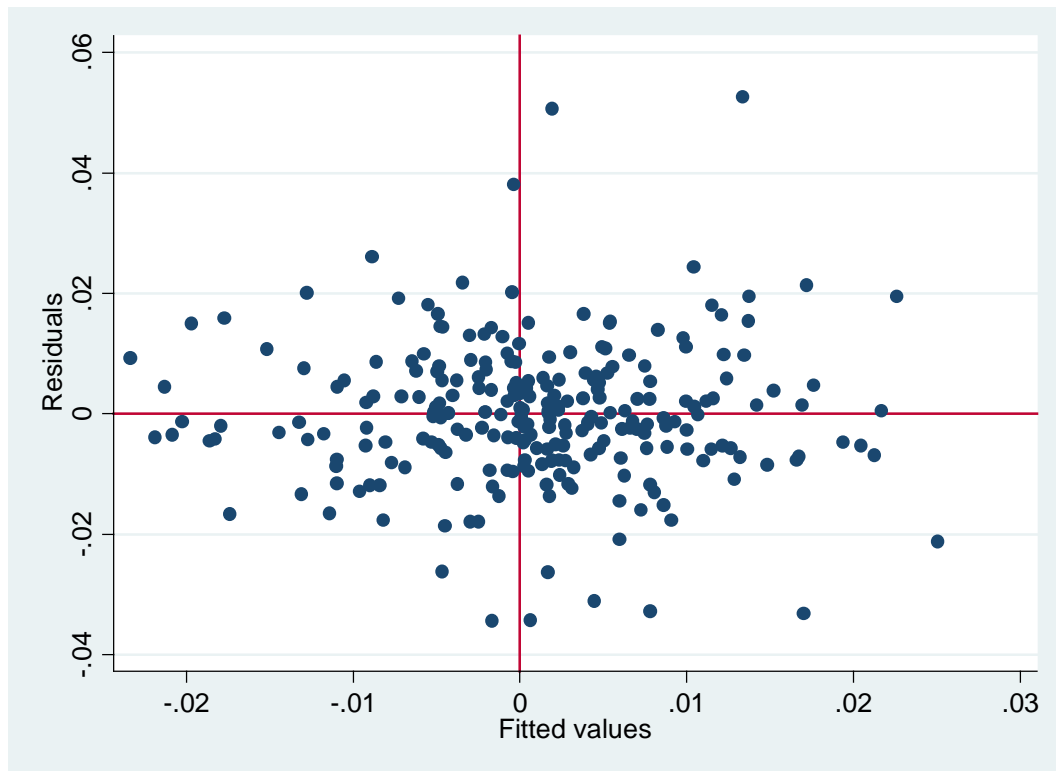


Figure 13: National Grid - residuals against fitted values

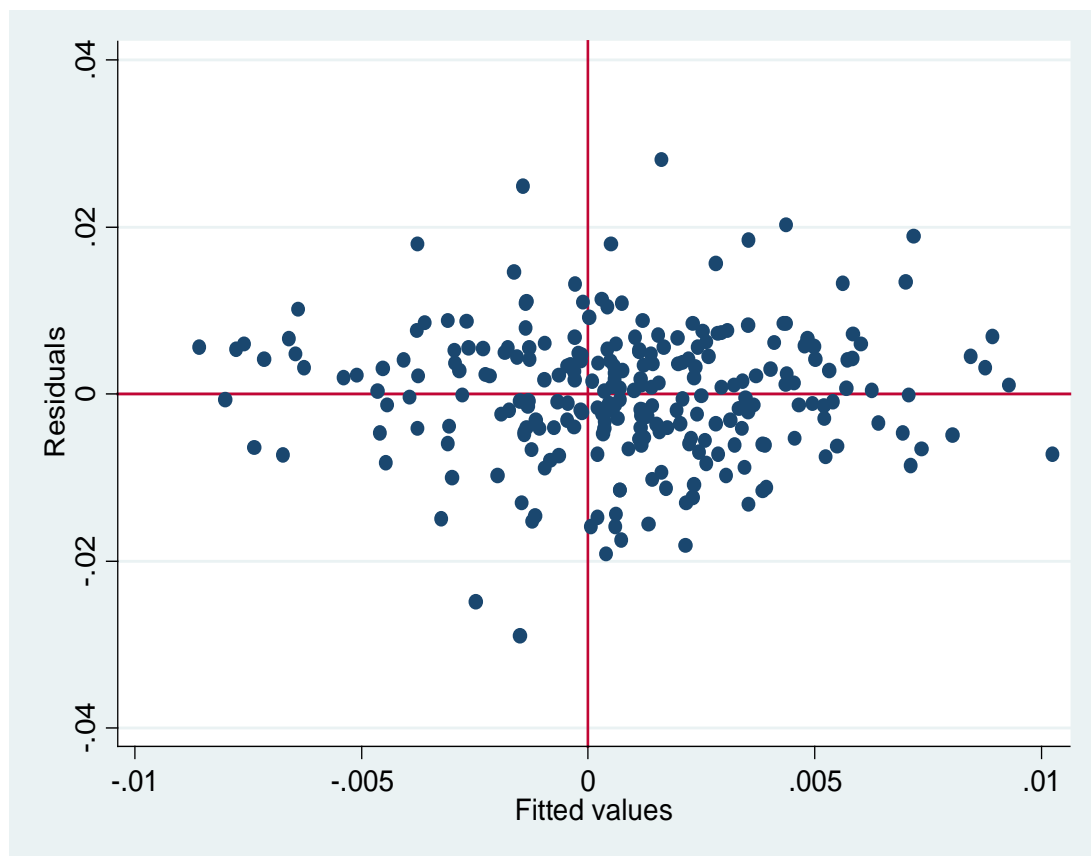


Figure 14: Pennon Group – residuals against fitted values

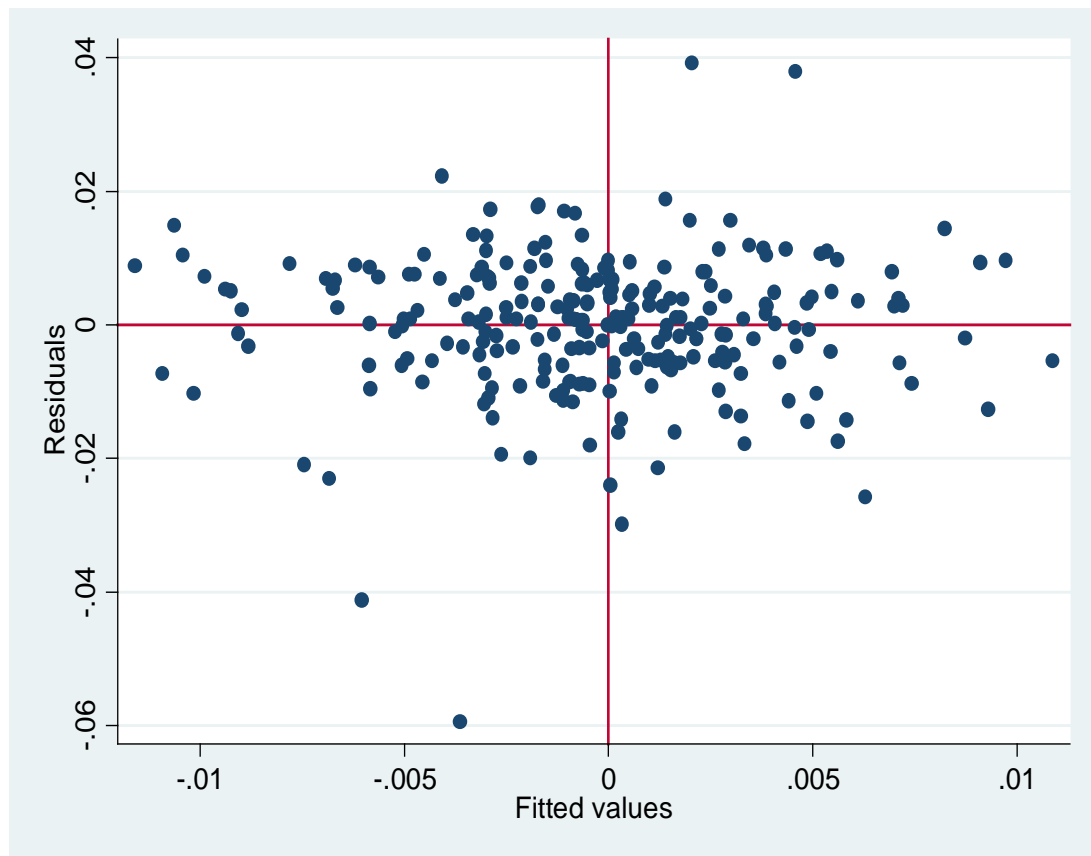


Figure 15: Severn Trent – residuals against fitted values

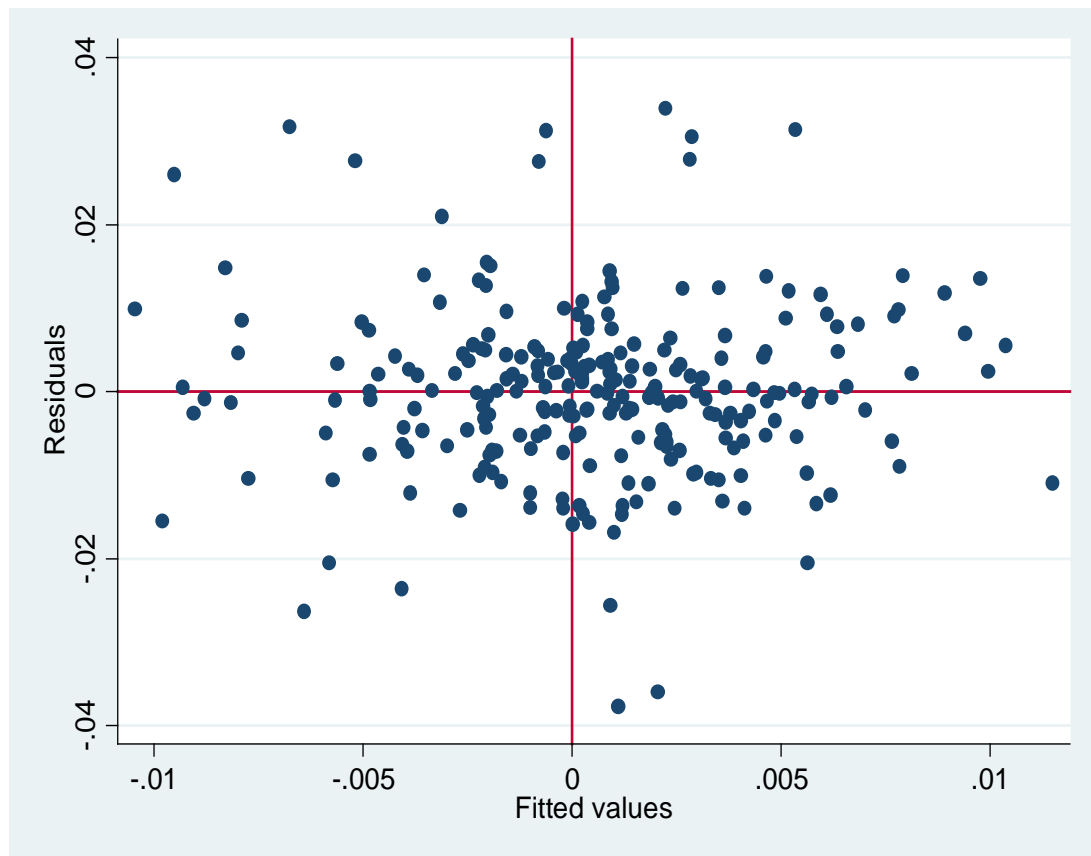
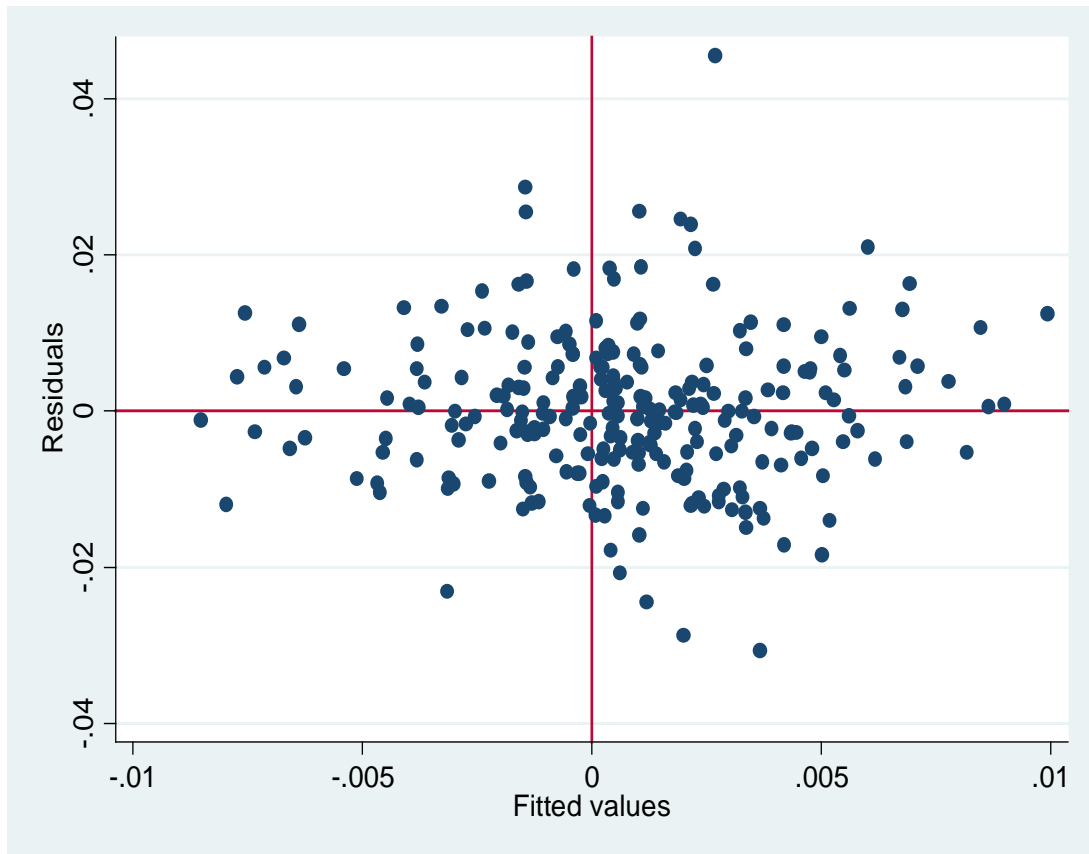


Figure 16: United Utilities – residuals against fitted values



We also examine whether there is change in the pattern of residuals over time. Figure 17 to Figure 21 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-Share.

Figure 17: BT - residuals over time

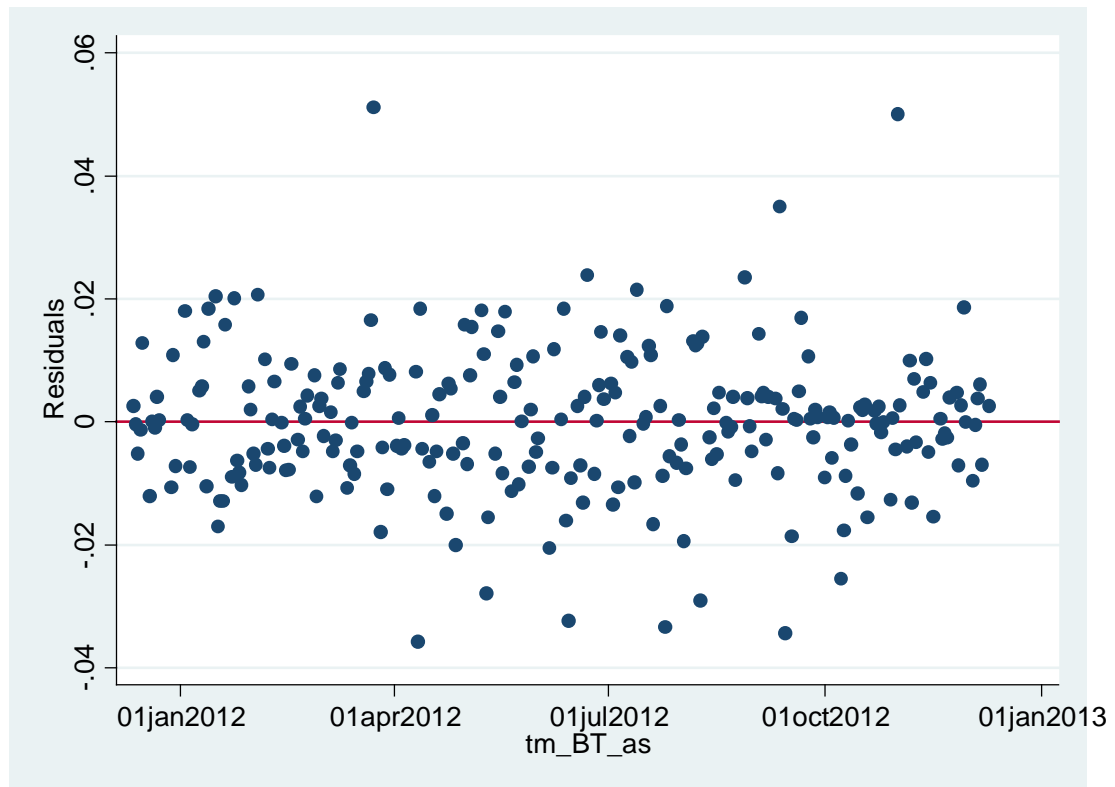


Figure 18: National Grid – residuals over time

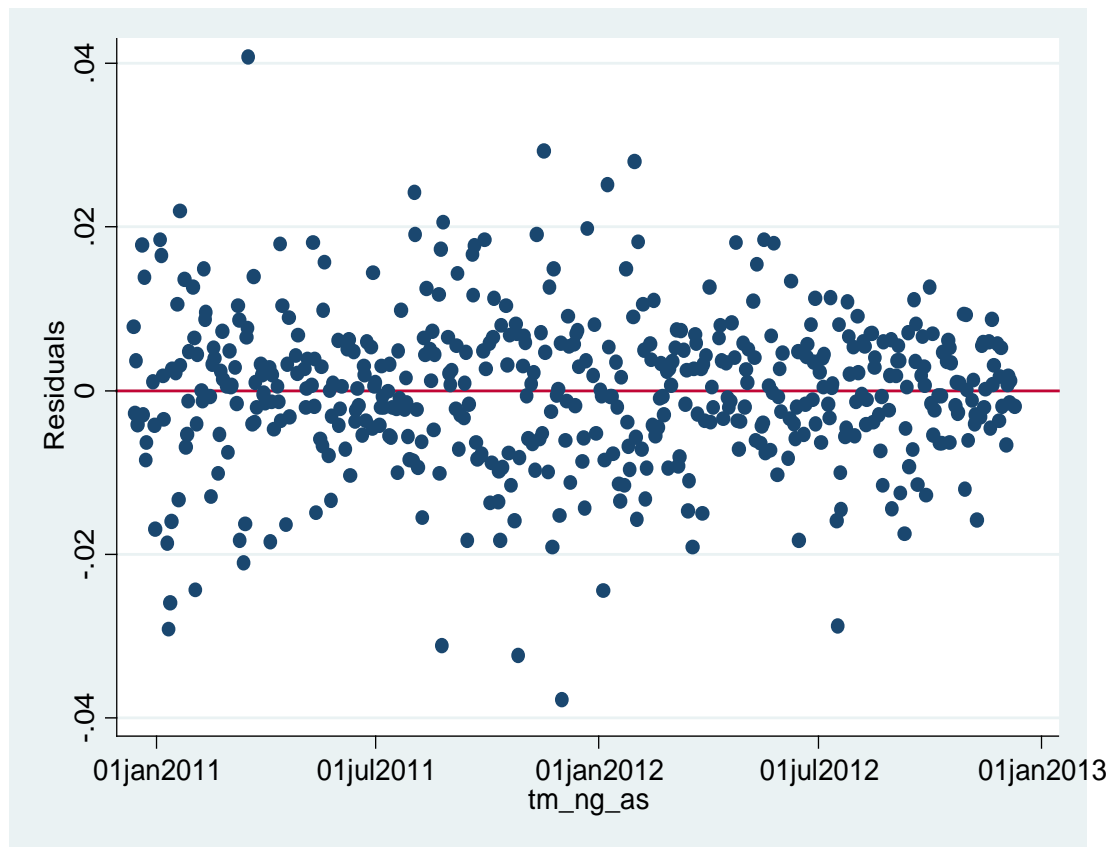


Figure 19: Pennon Group – residuals over time

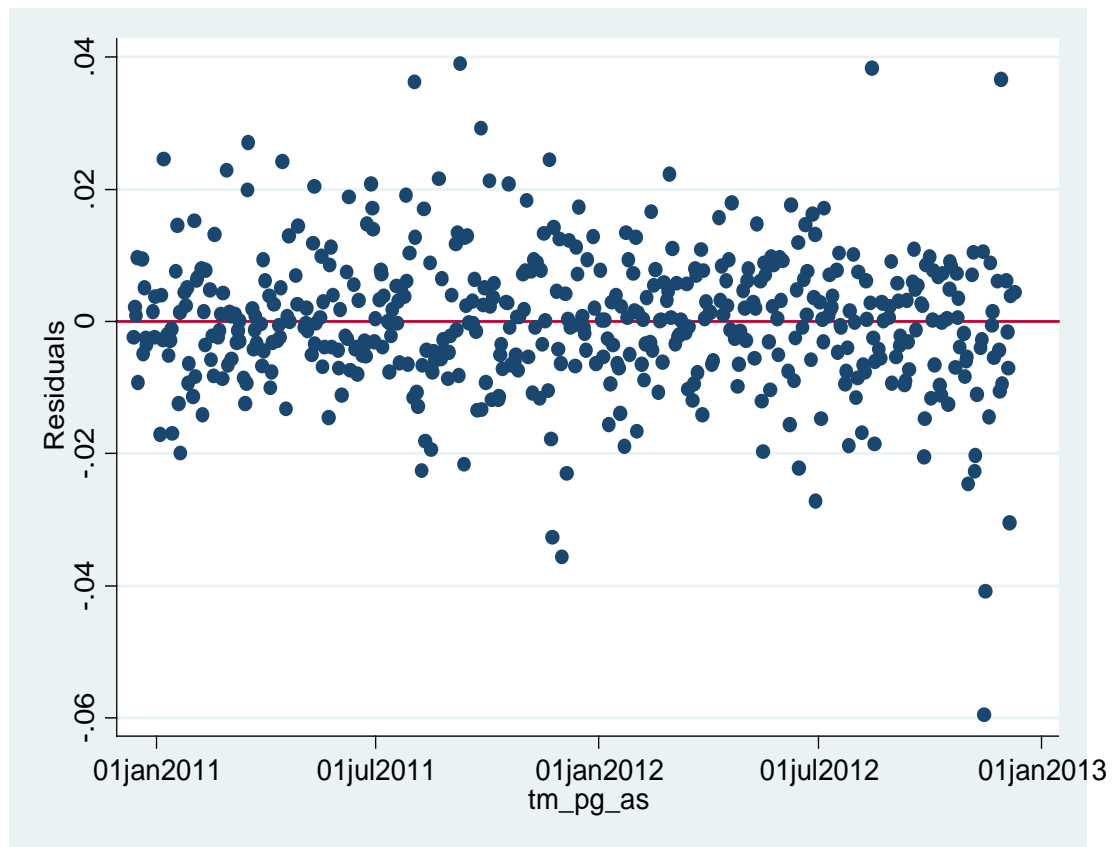


Figure 20: Severn Trent – residuals over time

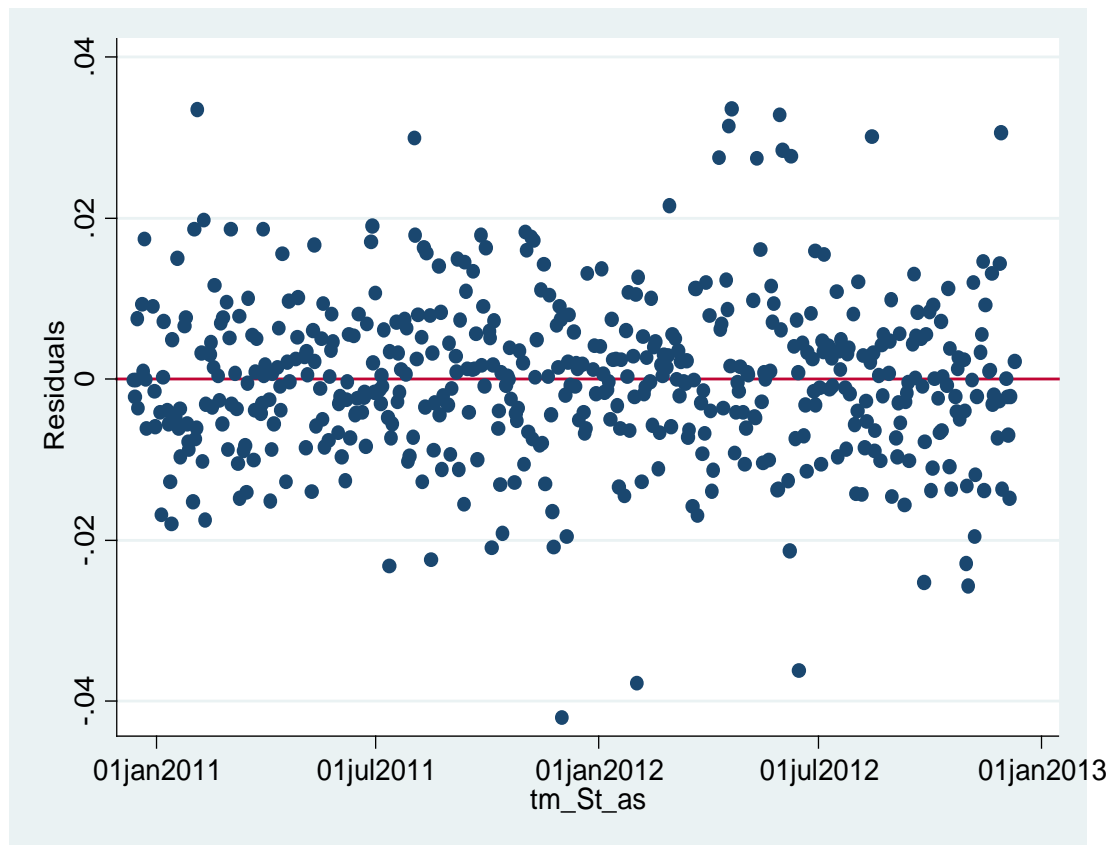
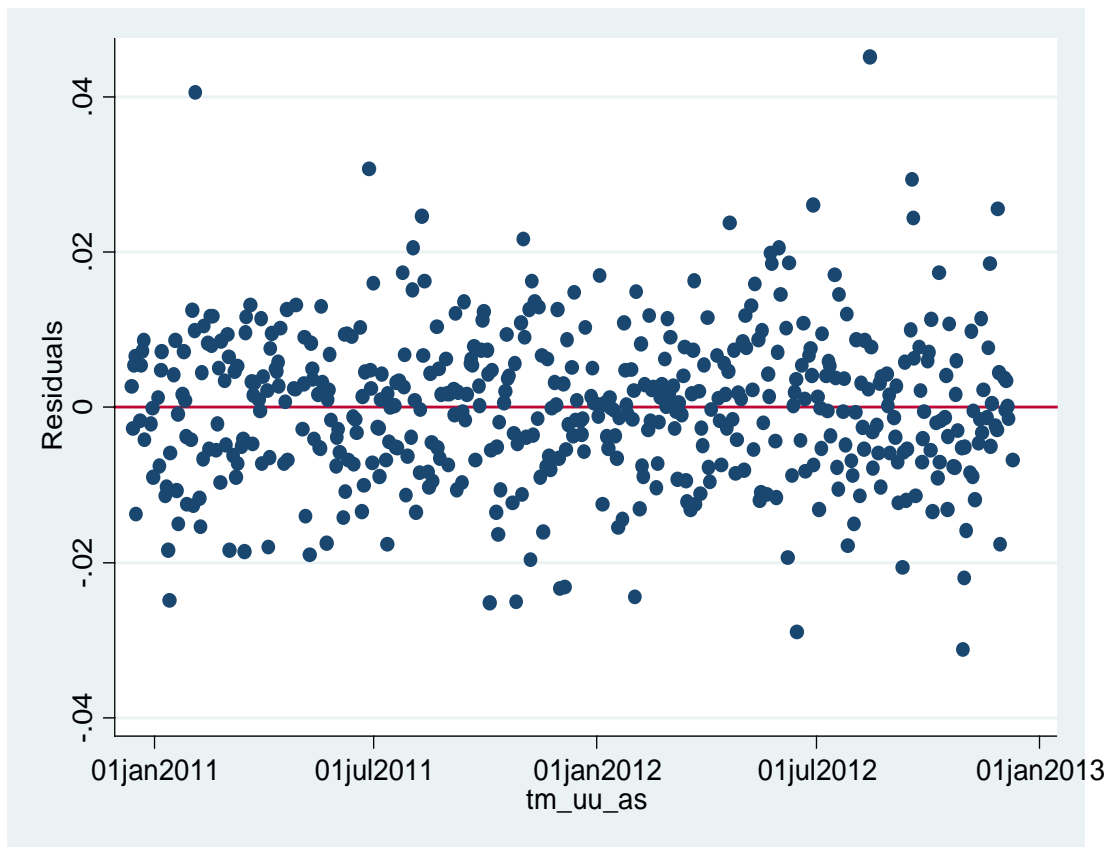


Figure 21: United Utilities – residuals over time



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 estimate for BT against the FTSE All-Share.

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
<i>BT</i>						
All World	1.90	0.39	No	4.26	0.12	No
All Share	2.50	0.29	No	9.70	0.01	Yes
<i>UK Utility Peer Group</i>						
<i>National Grid</i>						
All World	2.66	0.27	No	3.25	0.20	No
All Share	1.50	0.47	No	2.25	0.32	No
<i>Pennon Group</i>						
All World	0.08	0.96	No	1.80	0.41	No
All Share	0.34	0.85	No	1.07	0.59	No
<i>Severn Trent</i>						
All World	5.74	0.06	No	1.46	0.48	No
All Share	1.96	0.38	No	0.03	0.99	No
<i>United Utilities</i>						
All World	2.12	0.35	No	2.21	0.33	No
All Share	1.85	0.40	No	1.84	0.40	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. The effects of this auto-correlation are that standard errors will over-estimate the precision of the regression and that the OLS betas no longer represent the least variance estimator.

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

	1 yr		2 yr	
	DW Stat	Serial Correlation	DW Stat	Serial Correlation
<i>BT</i>				
All World	1.922	No	1.926	No
All Share	1.644	Yes	1.743	Yes
<i>UK Utility Peer Group</i>				
<i>National Grid</i>				
All World	1.540	Yes	1.562	Yes
All Share	1.555	Yes	1.585	Yes
<i>Pennon Group</i>				
All World	1.519	Yes	1.597	Yes
All Share	1.541	Yes	1.599	Yes
<i>Severn Trent</i>				
All World	1.595	Yes	1.649	Yes
All Share	1.564	Yes	1.639	Yes
<i>United Utilities</i>				
All World	1.575	Yes	1.543	Yes
All Share	1.547	Yes	1.552	Yes

Robust regression and Generalised Least Squares

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). We also performed a fix for the presence of autocorrelation. In the presence of autocorrelation, the standard OLS and robust regression betas are unbiased, but they are no longer least variance estimators. We therefore performed a generalised least squares regression, which addresses the presence of autocorrelation in the residuals and results in an unbiased and least variance estimator. The similarity in results provides confidence that neither heteroscedascity nor autocorrelation are significantly affecting our beta estimates.

Table 6: Robust and GLS regressions and standard errors – up-to-date data

	1 yr					2 yr				
	OLS Beta	SE	Robust SE	GLS Beta	GLS SE	Beta	SE	Robust SE	GLS Beta	GLS SE
<i>BT</i>										
All World	1.11	0.12	0.12	1.07	0.11	1.03	0.07	0.08	1.06	0.07
All Share	0.99	0.08	0.09	0.98	0.08	1.01	0.05	0.06	1.01	0.06
<i>UK Utility Peer Group</i>										
<i>National Grid</i>										
All World	0.44	0.08	0.07	0.44	0.07	0.40	0.05	0.05	0.40	0.05
All Share	0.38	0.06	0.05	0.38	0.05	0.42	0.04	0.04	0.42	0.04
<i>Pennon Group</i>										
All World	0.37	0.11	0.11	0.37	0.11	0.47	0.05	0.06	0.47	0.06
All Share	0.45	0.07	0.08	0.44	0.07	0.51	0.04	0.05	0.51	0.05
<i>Severn Trent</i>										
All World	0.35	0.11	0.13	0.35	0.13	0.48	0.05	0.06	0.49	0.06
All Share	0.44	0.07	0.08	0.44	0.08	0.51	0.04	0.04	0.51	0.04
<i>United Utilities</i>										
All World	0.29	0.10	0.09	0.29	0.09	0.45	0.05	0.05	0.45	0.05
All Share	0.37	0.07	0.06	0.37	0.06	0.47	0.04	0.04	0.47	0.04
<i>Peer Group Average</i>										
All World	0.36			0.36		0.45			0.45	
All Share	0.41			0.41		0.48			0.48	

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 22 to

Figure 26 show histograms for two-year FTSE All-Share regressions.

Figure 22: Studentized residuals - BT

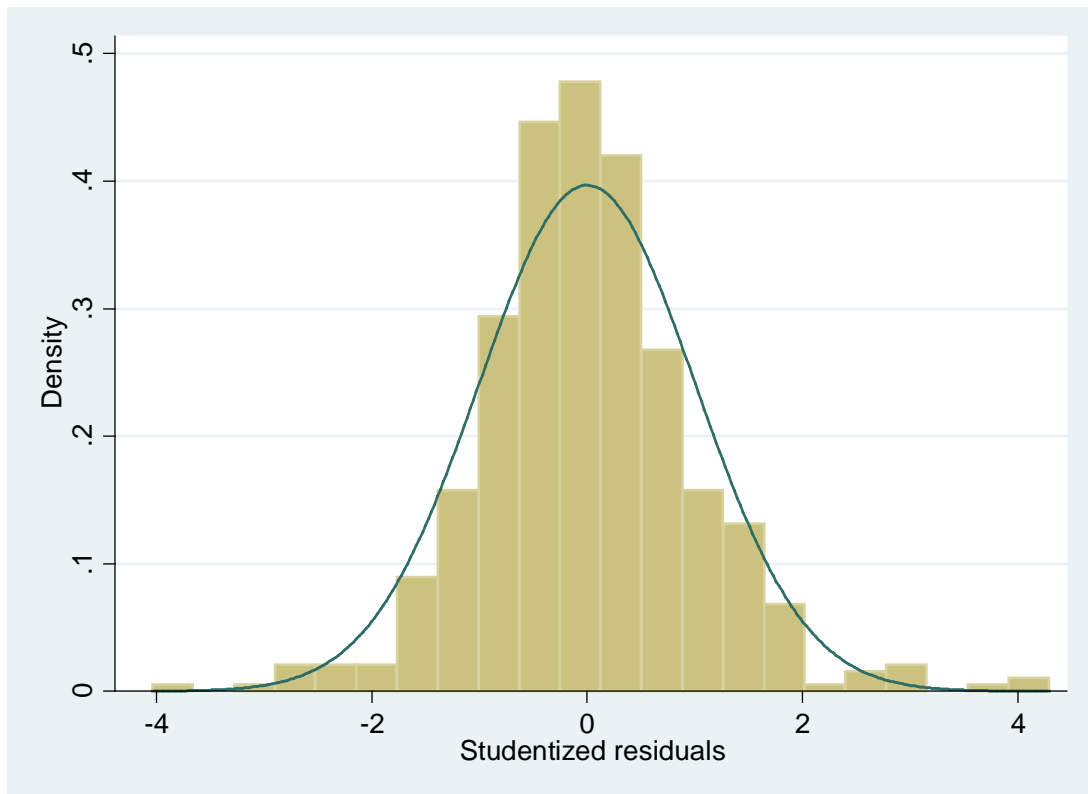


Figure 23: Studentized residuals – National Grid

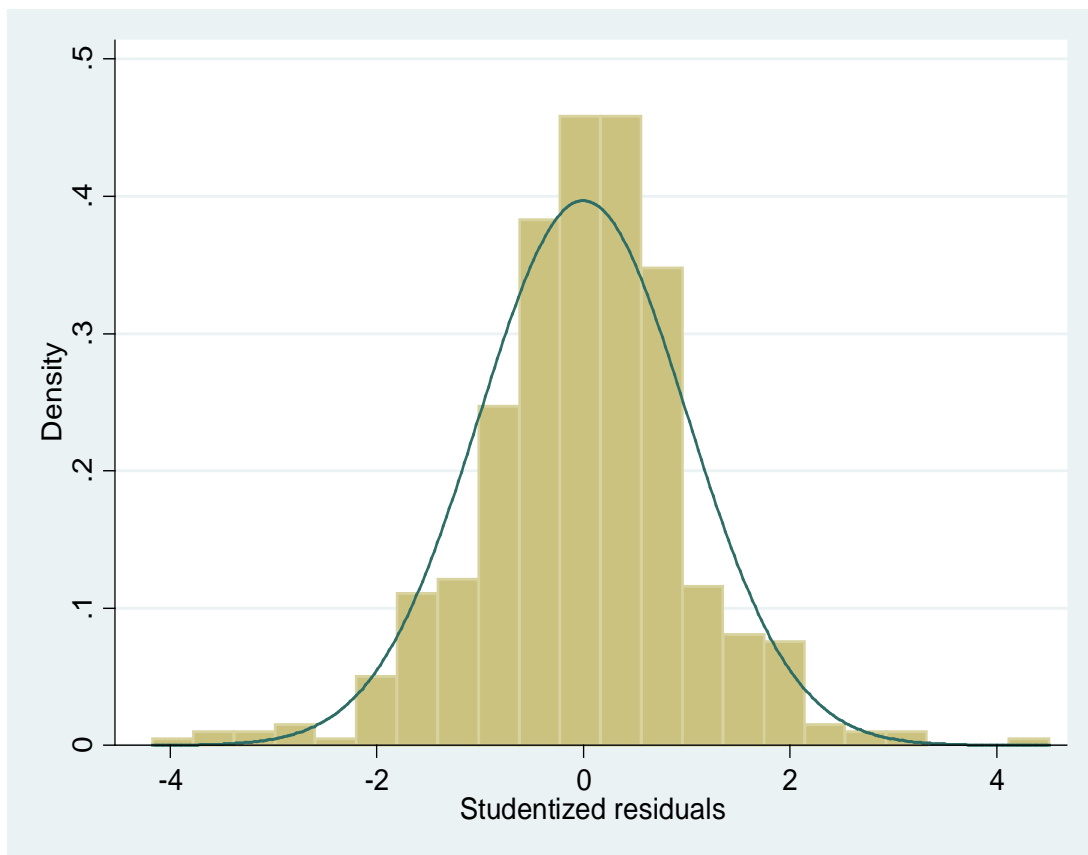


Figure 24: Studentized residuals – Pennon Group

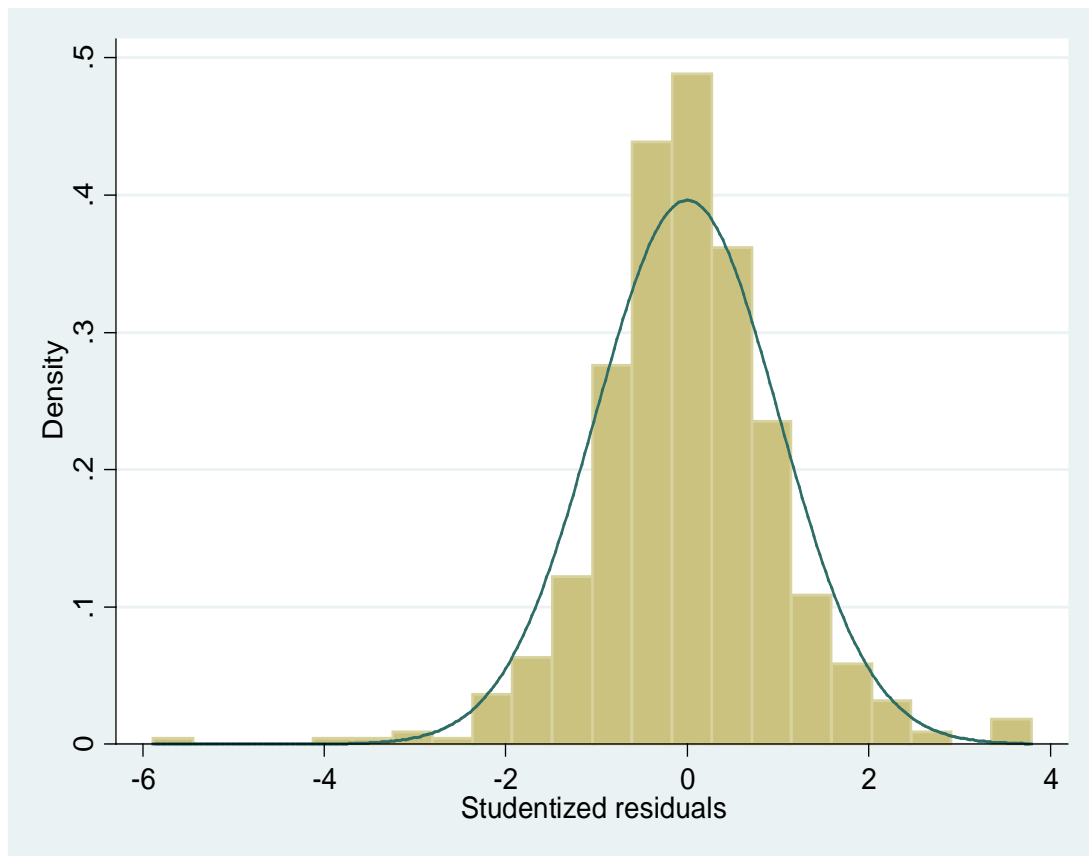


Figure 25: Studentized residuals – Severn Trent

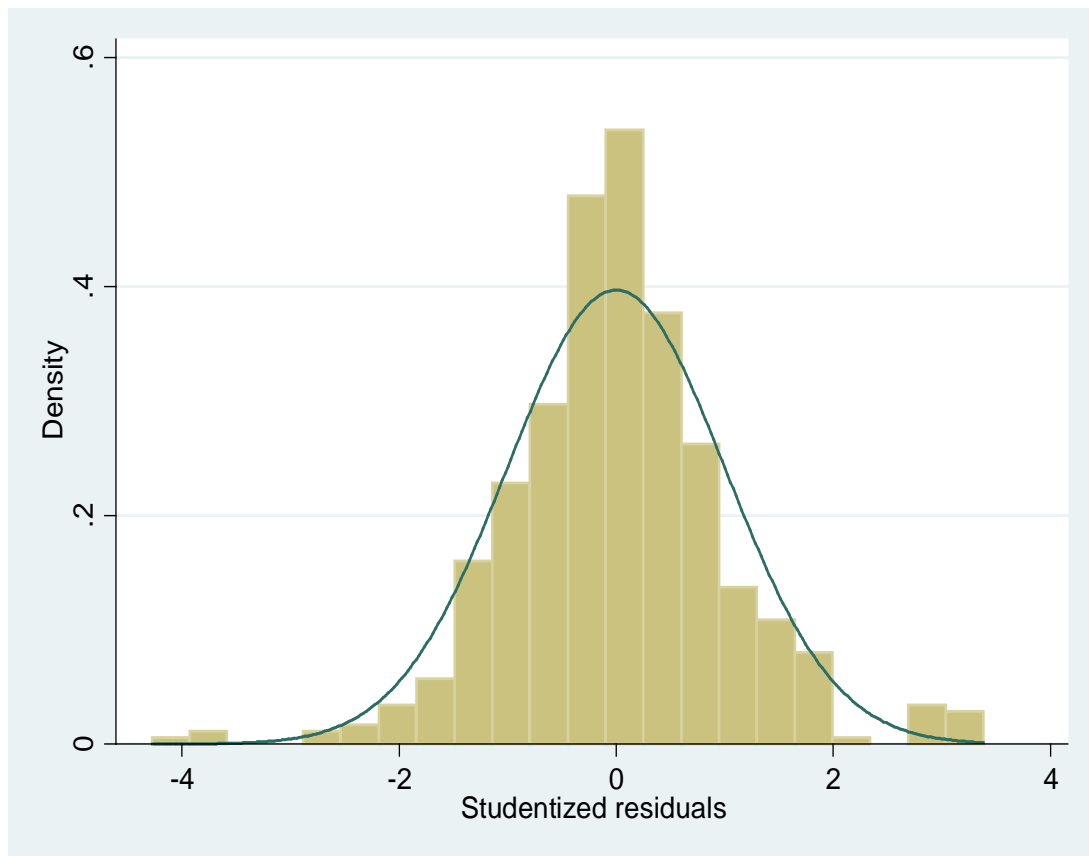
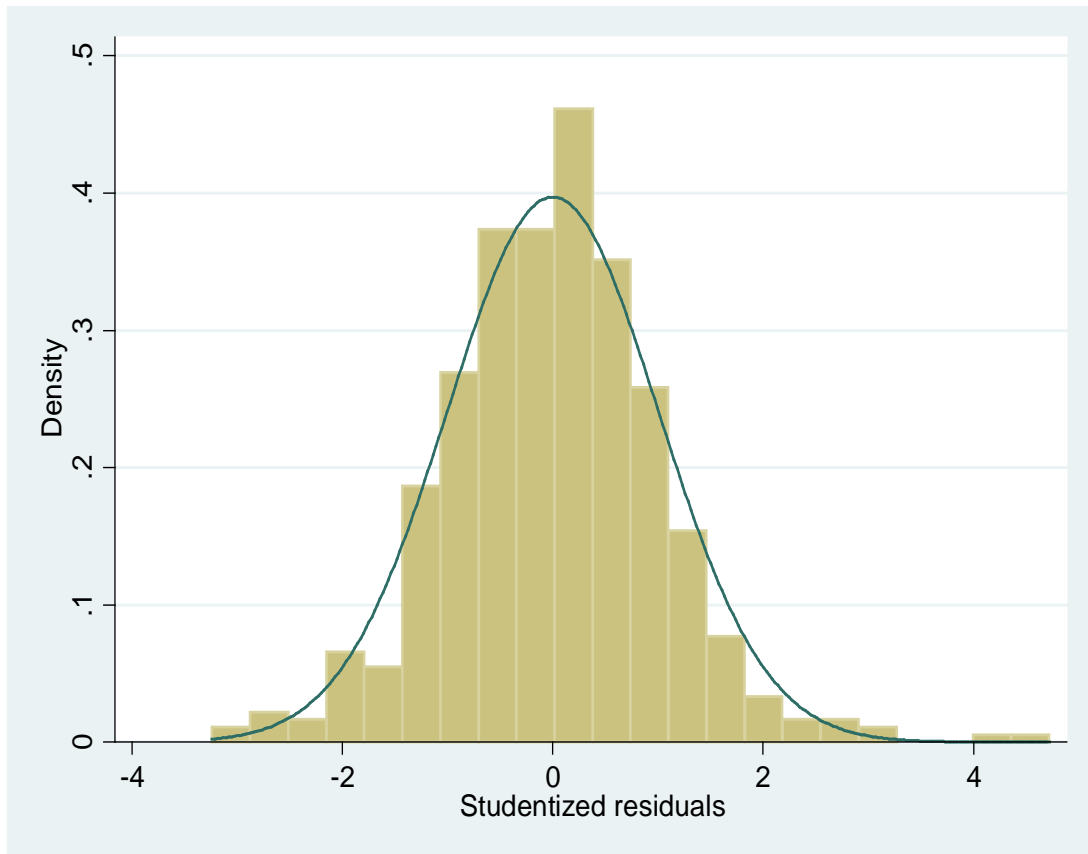


Figure 26: Studentized residuals – United Utilities



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
14-Jun-12	03-Feb-12	04-May-12	31-Aug-11
06-Jun-12	14-Jun-12	23-Mar-12	31-Oct-11
01-Nov-12	23-Aug-11	18-May-12	23-Mar-12
10-Apr-12	07-Sep-11	23-Apr-12	08-May-12
27-Jul-12	31-Aug-11	12-Apr-12	06-Jun-12
12-Apr-12	23-Mar-12	14-Sep-12	01-Nov-12
23-Apr-12	05-Oct-11	22-Jun-12	03-Feb-11
26-Jul-12	01-Nov-12	08-May-12	02-Dec-11
09-Aug-12	08-Dec-11	06-Jun-12	14-Sep-12
14-Sep-12	03-Jan-12	01-Nov-12	05-Sep-11
03-Feb-12	02-Sep-11	14-Jun-12	10-Aug-11
03-Jan-12	04-Aug-11	12-Sep-12	02-Sep-11
23-Mar-12	18-Aug-11	03-Feb-12	08-Aug-11
	10-Aug-11	25-Jul-12	05-Aug-11
	02-Aug-11	11-Apr-12	09-Aug-11
	29-Jul-11	03-Jan-12	04-Oct-11
	21-Sep-11	26-Jul-12	12-Sep-12
	30-Aug-11		03-Feb-12
	31-Oct-11		12-Aug-11
	05-Aug-11		04-May-11
	09-Aug-11		27-Sep-11
	04-Oct-11		11-Apr-12
	24-Aug-11		04-Aug-11
	09-Aug-12		06-Oct-11
	28-Jul-11		03-Jan-12
	30-Sep-11		24-Aug-11
	22-Sep-11		01-Nov-11
	12-Aug-11		05-Oct-11
			08-Mar-11

Table 8 compares the beta estimates obtained using standard OLS and GLS techniques with those obtained through the iterative regression giving less weight to outliers and through a regression with all influential outliers removed. Figure 27 to Figure 31 then plot the rolling estimates of the betas for BT and the other UK utilities against the FTSE All-Share. They compare the results of the standard OLS regression, robust regressions and regressions omitting all “outliers”. The close 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 OLS	GLS	Robust	No Outliers	Number of Outliers	Standard OLS	GLS	Robust	No Outliers	Number of Outliers
<i>BT</i>										
All World	1.11	1.07	1.07	1.11	13	1.03	1.06	1.03	1.03	28
All Share	0.99	0.98	0.99	0.99	17	1.01	1.01	1.01	1.01	29
<i>UK Utility Peer Group</i>										
<i>National Grid</i>										
All World	0.44	0.44	0.44	0.44	10	0.40	0.40	0.45	0.40	34
All Share	0.38	0.38	0.34	0.38	12	0.42	0.42	0.45	0.42	36
<i>Pennon Group</i>										
All World	0.37	0.37	0.30	0.37	12	0.47	0.47	0.50	0.47	31
All Share	0.45	0.44	0.37	0.45	13	0.51	0.51	0.51	0.51	29
<i>Severn Trent</i>										
All World	0.35	0.35	0.43	0.35	18	0.48	0.49	0.53	0.48	30
All Share	0.44	0.44	0.47	0.44	20	0.51	0.51	0.53	0.51	33
<i>United Utilities</i>										
All World	0.29	0.29	0.26	0.29	12	0.45	0.45	0.45	0.45	29
All Share	0.37	0.37	0.37	0.37	12	0.47	0.47	0.49	0.47	27
<i>Peer Group Average</i>										
All World	0.36	0.36	0.35	0.36		0.45	0.45	0.48	0.45	
All Share	0.41	0.41	0.39	0.41		0.48	0.48	0.49	0.48	

Figure 27: One-year beta against FTSE All-Share – BT

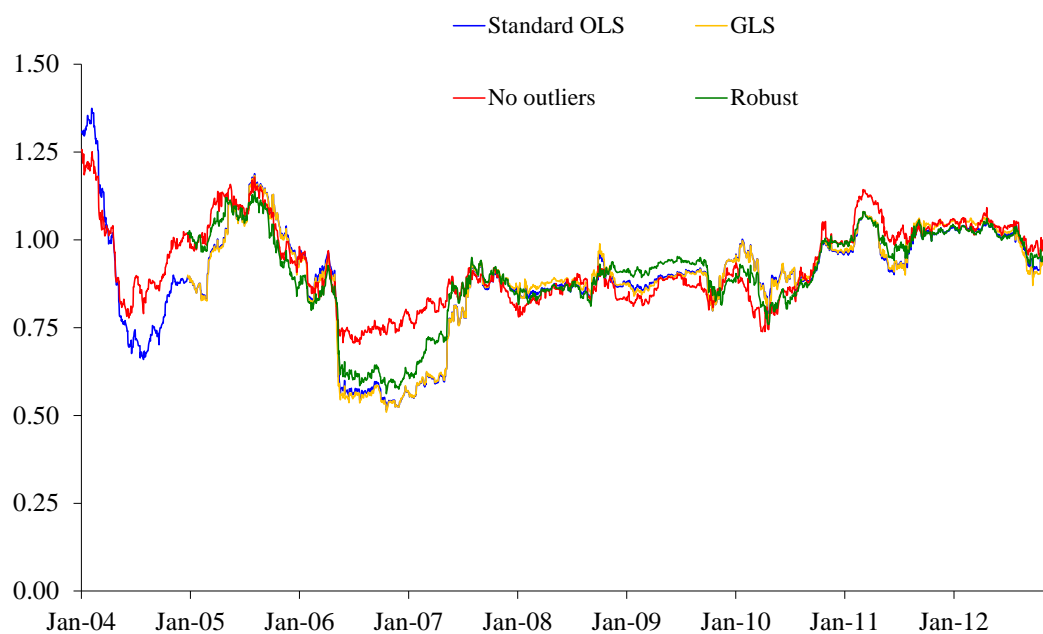


Figure 28: One-year beta against FTSE All-Share – National Grid

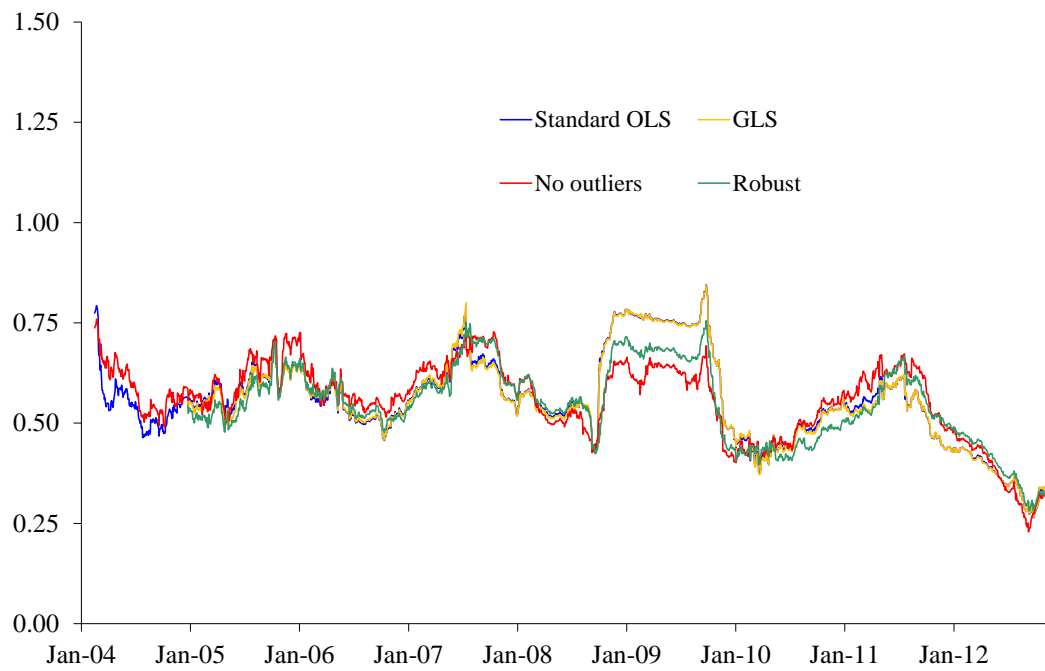


Figure 29: One-year beta against FTSE All-Share – Pennon Group

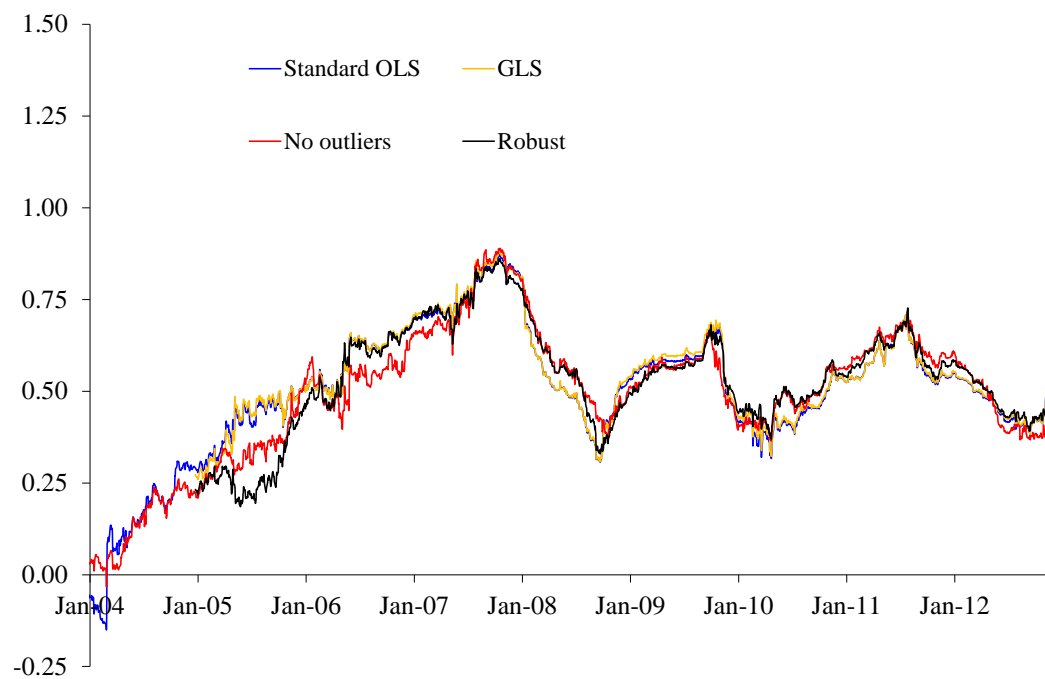


Figure 30: One-year beta against FTSE All-Share – Severn Trent

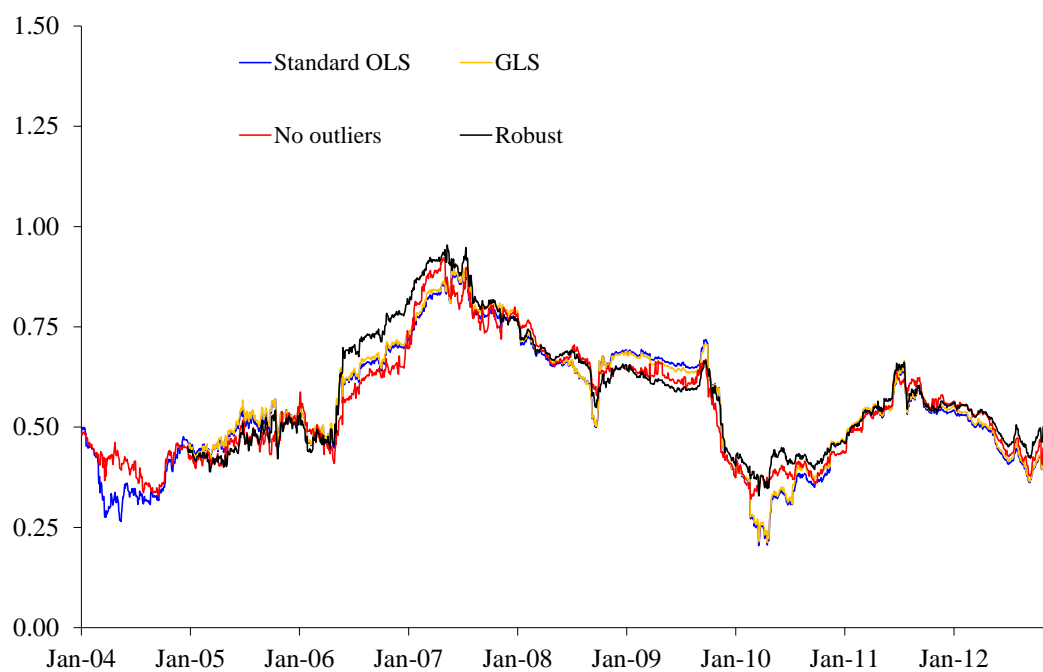


Figure 31: One-year beta against FTSE All-Share – United Utilities

