UPDATED ESTIMATE OF

BT'S EQUITY BETA

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1 Introduction and Summary of Findings

Ofcom has asked us to update previous estimates of BT's equity beta (the "BT beta") to take into account the latest market data. This document is an updated version of our November 2008 report, and includes data up to and including March 10th 2009. Table 1 shows our estimates of the beta relative to both UK-based and global market indices, and across a number of timeframes.

Table 1: Estimates of BT equity beta

BT beta measured against the FTSE allshare index

Period	1 year	2 year	5 year
Start date	11/03/2008	11/03/2007	11/03/2004
End date	10/03/2009	10/03/2009	10/03/2009
Beta	0.85	0.85	0.84
Standard error	0.07	0.05	0.03

BT beta measured against the FTSE allworld index

Period	1 year	2 year	5 year
Start date	11/03/2008	11/03/2007	11/03/2004
End date	10/03/2009	10/03/2009	10/03/2009
Beta	0.83	0.85	0.84
Standard error	0.09	0.06	0.04

Table 2 shows also a number of estimates for earlier time periods, illustrating that earlier beta estimates would have been different. The figures in bold in Table 2 are the most recent estimates (i.e., the same ones shown in Table 1 above).

Table 2: Estimates for earlier time periods

BT beta measured against the FTSE allshare index

Period	1 year	1 year	1 year	1 year	**1 year**	2 years	2 years	2 years	2 years	**2 years**
Start date	01/03/2005	01/03/2006	01/03/2007	11/10/2007	**11/03/2008**	28/02/2004	01/03/2005	01/03/2006	11/10/2006	**11/03/2007**
End date	28/02/2006	28/02/2007	29/02/2008	10/10/2008	**10/03/2009**	28/02/2006	28/02/2007	29/02/2008	10/10/2008	**10/03/2009**
Beta	0.82	0.60	0.84	0.94	**0.85**	0.83	0.67	0.78	0.93	**0.85**
Standard error	0.12	0.10	0.06	0.07	**0.07**	0.08	0.08	0.05	0.05	**0.05**

BT beta measured against the FTSE allworld index

Period	1 year	1 year	1 year	1 year	**1 year**	2 years	2 years	2 years	2 years	**2 years**
Start date	01/03/2005	01/03/2006	01/03/2007	11/10/2007	**11/03/2008**	28/02/2004	01/03/2005	01/03/2006	11/10/2006	**11/03/2007**
End date	28/02/2006	28/02/2007	29/02/2008	10/10/2008	**10/03/2009**	28/02/2006	28/02/2007	29/02/2008	10/10/2008	**10/03/2009**
Beta	0.64	0.67	0.95	0.96	**0.83**	0.73	0.65	0.87	0.97	**0.85**
Standard error	0.15	0.14	0.10	0.10	**0.09**	0.09	0.10	0.08	0.07	**0.06**

Each of the most recent estimates is about 0.1 (one to two standard deviations) below the corresponding November 2008 estimate. Material changes over time in the estimated beta raise important questions, not least because the measurement procedure assumes implicitly that beta is constant within the measurement window. We must therefore ask whether this change in the estimated beta reflects a shift in the fundamental relationship between returns on BT's equity and on the overall market, or is a statistical artefact: has

the equity beta changed, or is it that these are different estimates of the same underlying parameter?

We have therefore undertaken two analyses. First, we look to see whether changes in gearing might explain some or all of the recent changes in the estimated beta. All else being equal, higher gearing will give a higher equity beta. Second, we examine data to see whether returns from a relatively small number of days may be having a significant influence on the beta estimates. For the avoidance of doubt, we are not however suggesting that returns from "unusual" days should be ignored. The performance of BT equity in unusual circumstances may be an important driver of its overall cost of capital.

Changes in gearing

Although BT's gearing[1] was fairly constant until the beginning of 2007, it has subsequently risen (indeed more than doubled) as a result of falls in BT's share price, and in the last year has gone from 34% to 66%.[2] We can partially remove the effect of changes in gearing by "re-levering" the beta estimates[3] in Table 2 to constant gearing.[4] The results are shown in Table 3: the "relevered beta" is an estimate of what the equity beta would have been if BT had had gearing of 38% during the relevant time period.[5] We assume that the debt beta might be in the range zero to 0.2, so we present re-levered estimates for extremes of this range.

[1] In this report we define gearing as net debt divided by the sum of net debt and market capitalisation. For convenience we use book values of debt. A more accurate approach would use the market value of debt, but we do not expect the difference to be very significant.

[2] See Table 6 for details.

[3] For example, the re-levered beta of 0.90 shown in the first column of Table 3 is an estimate of what the equity beta would have been in the year to 28/2/2006, if the leverage had been 38% instead of 32%. This "re-levering" is similar in concept to the regulatory practice of determining an asset beta which may then be used to make a notional equity beta at the notional gearing assumed by the regulator.

[4] This is only a partial correction because we continue to assume implicitly that gearing does not change during the beta estimation window. We have also carried out an alternative estimation that does not rest on this assumption (see below).

[5] We choose 38% because that was the average gearing in the year to November 2008 (the date of our last report). Note that the relevering follows a standard formula of corporate finance (see *Principles of Corporate Finance* (8th edition), Brealey Myers & Allen, p. 518).

Table 3: Equity beta estimates relevered to 38% gearing

BT beta measured against the FTSE allshare index

Period	1 year	1 year	1 year	1 year	**1 year**
End date	28/02/2006	28/02/2007	29/02/2008	10/10/2008	**10/03/2009**
Measured beta	0.82	0.60	0.84	0.94	**0.85**
Average gearing	32%	25%	30%	38%	**50%**
Beta relevered to 38% gearing, debt beta = 0	0.90	0.73	0.95	0.94	**0.68**
Beta relevered to 38% gearing, debt beta = 0.2	0.88	0.68	0.92	0.94	**0.72**

BT beta measured against the FTSE allworld index

Period	1 year	1 year	1 year	1 year	**1 year**
End date	28/02/2006	28/02/2007	29/02/2008	10/10/2008	**10/03/2009**
Measured beta	0.64	0.67	0.95	0.96	**0.83**
Average gearing	32%	25%	30%	38%	**50%**
Beta relevered to 38% gearing, debt beta = 0	0.70	0.81	1.07	0.96	**0.66**
Beta relevered to 38% gearing, debt beta = 0.2	0.68	0.77	1.05	0.96	**0.70**

Notes
Average gearing is the average of the quarter-end gearing figures for the quarters most nearly co-incident with the estimation window. The re-levering assumes a gearing of 38%.

While bearing in mind that the analysis involves a simplifying approximation (the assumption that gearing is constant over the estimation window),[6] we observe that the figures in Table 3 suggest that the observed increase in BT's estimated equity beta between the end of February 2008 and October 2008 may be attributable to changes in gearing. In particular, with constant gearing, the estimate against the Allshare is almost unchanged (0.95 vs 0.94 at zero debt beta, 0.92 vs 0.95 at debt beta of 0.2) between the estimates ending 29/2/08 and 10/10/08, while against the Allworld it actually falls from 1.07 to 0.96.

However, since October 2008 the estimated beta has fallen again, although the increase in gearing has continued. Moreover, the large change in gearing in the last year raises an additional issue. The standard procedures for estimating beta implicitly assume that the underlying beta is constant over the time period used for estimation. The large change in gearing over the last year makes this assumption prima facie implausible. There is a risk that the most recent one-year estimates may be unreliable due to the fact that gearing is not constant.

As a preliminary step in addressing this issue, we also made an alternative estimation of the equity beta. To do so we constructed the "total returns" on holding BT equity and debt, and used it to estimate BT's asset beta. This method uses market values of both equity and debt and does not rest on an assumption that gearing is constant. We used this estimate of the asset beta to estimate BT's equity beta at 38% leverage, as shown in Table 4 below.

[6] We show below that relaxing this assumption makes very little difference.

Table 4: Estimates based on direct estimation of asset beta

	Allshare	Allworld
Start date	11/03/2008	11/03/2008
End date	10/03/2009	10/03/2009
Asset beta	0.43	0.42
Implied equity beta (38% leverage, zero debt beta)	0.70	0.68
Implied equity beta (38% leverage, 0.2 debt beta)	0.58	0.55

The implication of this analysis is that BT's equity beta may indeed have fallen. However, there are many other issues around interpretation of data from the last six months (including the assumed debt beta), so the analysis should be interpreted with caution.

Influence of unusual days

Figure 1 shows one and two year estimates of the BT equity beta on a "rolling basis", against the Allshare index.[7] The striking feature is the "cliff-edge" effect, with the beta estimate dropping significantly when the "window" changes by just a few days, bringing a small number of unusual days in mid to late May 2006 into the dataset. The one-year beta then rises sharply when these unusual days leave the window again.

Finally, the far right-hand side of Figure 1 shows the influence of recent data, including the small "spike" in beta estimation towards the end of 2008.

[7] The Appendix shows the equivalent graph for the Allworld index.

Figure 1: Rolling BT betas

A natural question is whether these unusual days are "outliers" that should be eliminated. In terms of finance theory, we are not aware of a clear argument for eliminating these days. However, at a minimum one ought to be aware of the extent to which the estimates are driven by a small number of data points, and of the extent to which those influential data points are outliers.

We have therefore tested the reliability of the statistical estimates using a variety of formal and informal statistical techniques. Our analysis suggests that the estimates are generally reliable, even though the dataset includes a number of outliers, and more recent market volatility may mean that some of the more recent estimates have slightly larger standard errors. We have examined the impact of removing the most influential outliers, and of giving less weight to outliers via a "robust regression".[8] Table 5 shows that the standard estimates are not significantly changed by removing or placing less weight on influential outliers (the latter approach is what is meant here by 'robust' regression).

[8] We report these analyses on a heuristic basis. In particular we note the lack of a good theoretical basis for removing outliers in this context.

Table 5: BT beta estimates controlling for outliers

BT beta measured against the FTSE allshare index

Regression	'Standard'	Influential outliers removed	'Robust'
Start date	11/03/2008	11/03/2008	11/03/2008
End date	10/03/2009	10/03/2009	10/03/2009
Beta	0.85	0.85	0.89
Standard error	0.07	0.06	0.05

We discuss the influence of "unusual" days on the fall in the one-year beta during 2006/7 in more detail below, where we show that although the dramatic fall in Figure 1 is due to only a small number of days, these days are not "influential outliers" and thus "robust" regression during this period would also have reported a low beta.

Conclusions

Our findings suggest that:

- Based on our regressions, it is reasonable to use a range of 0.8 to 1.0 for BT's current equity beta, on the basis that this would correspond to gearing of about 38%. A forward looking estimate would be higher to reflect the new, higher gearing. However this would not change the estimated asset beta, and hence would not change a standard regulatory estimation of the equity beta, where the measured beta is de-levered and re-levered at an assumed level of gearing.
- There is some evidence to favour a lower estimate for the beta (at 38% gearing), since the observed beta has not increased despite the much higher actual gearing. However this evidence should be interpreted with care.
- The more recent estimates are somewhat affected by the impact of current market turmoil in that there are a number of "unusual" days in this part of the data window which are "influential outliers".
- We would place less reliance on the more recent estimates of equity beta (since late 2008) for which BT's gearing was changing rapidly during part of the data window.
- The lower one-year beta estimates from mid 2006 to mid 2007 seem to be due to a small number of "unusual" days.[9]

[9] The estimate falls when the unusual days enter the regression window, and rises again when they leave, explaining the U-shaped portion of the rolling regression chart centred around December 2006.

2 Reliability of the Estimates

2.1 Changes in gearing

In this report we estimate BT's equity beta by regressing daily returns from holding BT's equity against daily returns from holding a wider market index. An implicit assumption is that the underlying parameter we are estimating—the equity beta—is constant over the estimation window. We normally expect equity beta to be higher if gearing is higher, other things equal. We therefore need to be cautious when, during the estimation window, gearing is changing, because this implies that the underlying parameter we are trying to estimate should be changing.

BT's gearing has increased significantly in recent months as its share price has fallen. Table 6 shows quarterly gearing figures, as well as a "current" estimate assuming that net debt and number of shares in issue have not changed since the end of 2008. [10]

Table 6: Evolution of BT gearing (April 2008 – March 2009)

Date	Net debt (£m)	Market capitalisation (£m)	Gearing
'Current'	11,073	5,815	66%
31/12/2008	11,073	10,468	51%
30/09/2008	9,749	12,398	44%
30/06/2008	10,496	15,384	41%
31/03/2008	9,467	18,252	34%

Notes
Quarterly net debt and market capitalisation from Bloomberg.
'Current' figure assumes the same net debt as at the end of 2008 and market capitalisation based on the change in share price since the end of 2008.

Since gearing has increased so much in the last year we think that the most recent one-year beta estimates may not be reliable. An alternative approach is to construct an index of the enterprise value of BT (value of debt plus market value of equity), and so calculate the returns on owning the asset. Using these returns we can then directly estimate the asset beta. We undertook this analysis, obtaining the results shown in Table 4.

2.2 Statistical tests

One set of concerns about statistical reliability relates to the "standard assumptions" that underlie classic regression, specifically that the error term in the regression follows a normal distribution and does not suffer from heteroscedasticity or auto-correlation. Failure to meet these conditions does not invalidate the regression estimates (i.e., the beta estimate), but it does have the following consequences:

[10] As noted earlier, for convenience we use book values of debt. A more accurate approach would use the market value of debt, but we do not expect the difference to be very significant.

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

2. In the presence of heteroscedasticity and/or autocorrelation, the beta estimate may be more uncertain (that is, OLS may under-estimate the standard error of the beta estimate).

3. Heteroscedasticity and/or auto-correlation may also indicate that the underlying regression is mis-specified.

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 estimates.

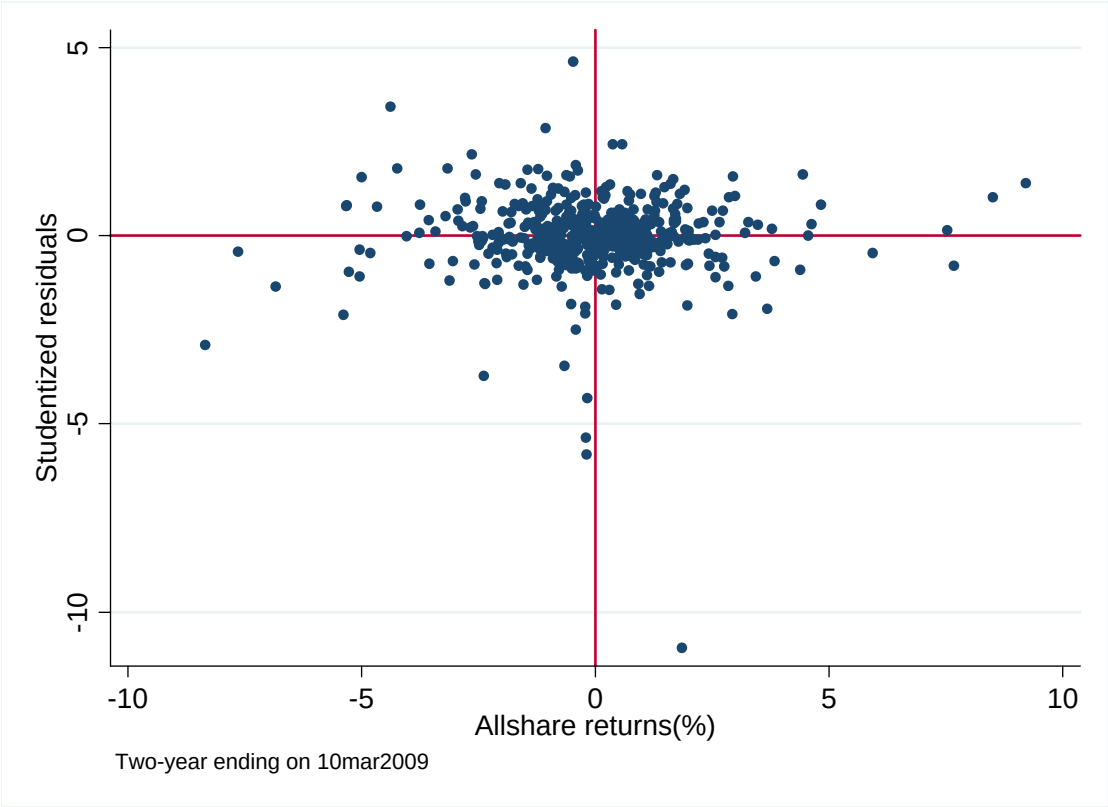
We have therefore carried out a number of standard diagnostic tests.

Tests for heteroscedasticity

Figure 2 shows a scatterplot of the residuals against the market index returns, for the two-year FTSE Allshare regression. Visual inspection does not reveal any clear pattern—the "vertical spread" does not appear to change in any systematic way as we move horizontally across the graph, as would be the case under typical sources of heteroscedasticity. However, there are clearly a number of outliers. We discuss the issue of outliers later in this paper.

The appendix provides the corresponding graphs for our other three main regressions (one year Allshare and one and two year Allworld). The conclusions are similar in all cases.

Figure 2: Plot of standardised residuals



Although Figure 2 does not show any obvious evidence of heteroscedasticity, we have also performed formal tests (the White test) for heteroscedasticity, reported in Table 7 below. The White test suggests that the tw0-year regression against the Allworld index show evidence of heteroscedasticity. Nevertheless, the heteroscedasticity does not seem to be making our regression results significantly less reliable: Table 1a and Table 2a in the appendix show both standard errors and "robust" standard errors, which correct for the presence of heteroscedasticity, and the two are almost the same.

Table 7: White test

Index	Allshare	Allworld	Allshare	Allworld
Start date	11/03/2007	11/03/2007	11/03/2008	11/03/2008
End date	10/03/2009	10/03/2009	10/03/2009	10/03/2009
White statistic	0.69	6.21	0.02	1.64
p-value	0.71	0.05	0.99	0.44

Tests for auto-correlation

We have performed a formal test (the Durbin-Watson test) for auto-correlation, reported in Table 8 below. The test shows no sign of auto-correlation.[11]

Table 8: Durbin-Watson test

Index	Allshare	Allworld	Allshare	Allworld
Start date	11/03/2007	11/03/2007	11/03/2008	11/03/2008
End date	10/03/2009	10/03/2009	10/03/2009	10/03/2009
d-stat	2.02	2.18	2.08	2.18

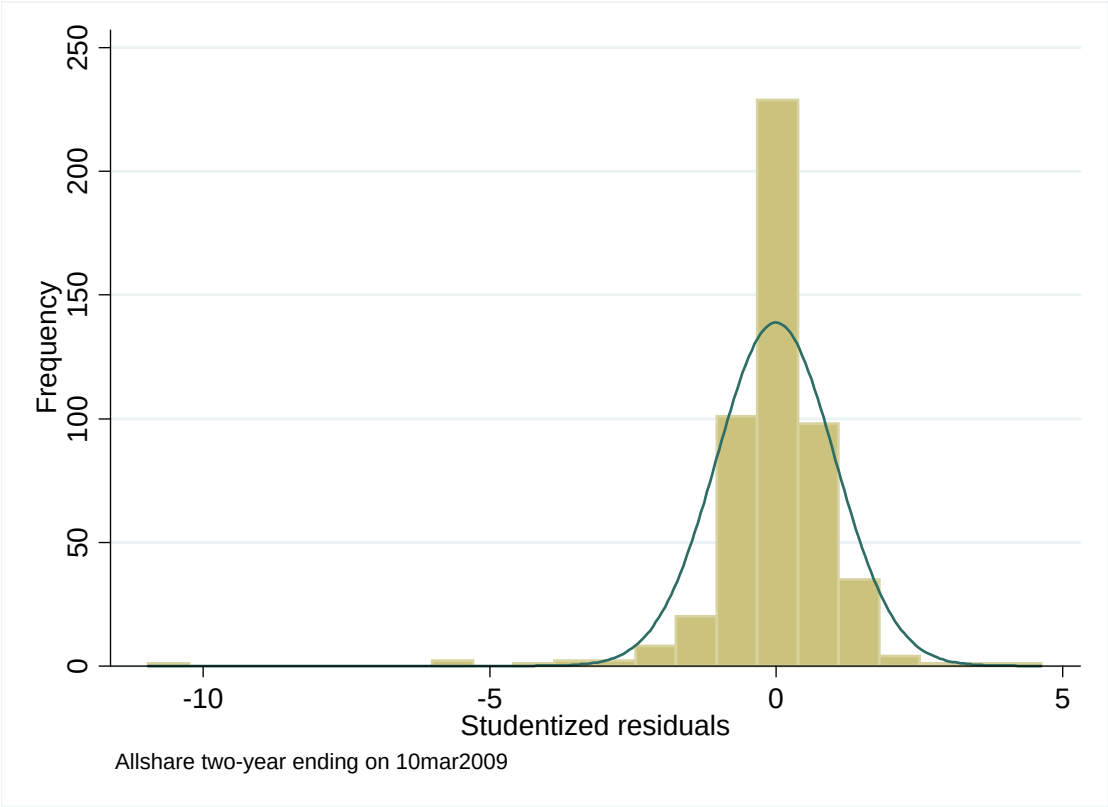
Notes:
The d-stat implies (5% confidence) no auto-correlation
if within the range 1.69 to 2.21.
(http://www.csus.edu/indiv/j/jensena/mgmt105/durbin.htm)

Normality and Outliers

To test for normality of the residuals we have plotted a histogram of the "studentised residuals", shown in Figure 3 (for the two-year FTSE Allshare regression). The curve superimposed on the histogram 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 sample size is practically indistinguishable from the standard normal distribution. The histogram looks like a normal distribution except for the outliers: there are a few too many points a large number of standard deviations away from zero.

[11] Auto-correlation would be signalled by a statistic outside the range 1.65 to 2.31.

Figure 3: Studentised residuals



There is no "right answer" to the treatment of outliers. In this case they clearly represent genuine data points. However, the presence of outliers can make standard OLS estimates less reliable.

As a guide to help understand the influence of outliers on our beta estimates we have carried out two analyses: looking at the impact of removing "influential outliers", and performing a "robust regression".

To identify influential 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 D score over 4/N (number of observations) as influential. Table 9 lists the observations with D scores over this threshold and which have studentized residuals of more than +/- 3.

Table 9: Outliers

Date	BT return (%)	Allshare return (%)	Cook's D	Residuals
07/02/2008	-9.80	-2.39	0.034	-3.72
31/07/2008	-11.99	-0.18	0.032	-5.82
31/10/2008	-19.00	1.86	0.200	-10.96
13/11/2008	8.89	-0.47	0.021	4.63
19/11/2008	3.13	-4.39	0.073	3.43
22/01/2009	-9.11	-0.18	0.018	-4.32
12/02/2009	-7.80	-0.66	0.013	-3.45
06/03/2009	-11.15	-0.20	0.027	-5.36

We recalculate the two-year Allshare regression excluding the influential outliers shown in Table 9. The results are reported in Table 10, and the same table also shows the

results of a 'robust' regression that assigns lower weight to outliers than OLS does. Table 5 above shows equivalent results for the one-year regression. Neither estimate is significantly affected by the outliers.

Table 10

BT beta measured against the FTSE allshare index

Regression	Normal	Influential outliers removed	'Robust'
Start date	11/03/2007	11/03/2007	11/03/2007
End date	10/03/2009	10/03/2009	10/03/2009
Beta	0.85	0.88	0.87
Standard error	0.05	0.04	0.03

We investigated the possible impact of recent financial turmoil by re-estimating beta excluding the most recent data. Table 11 shows that the estimated beta rises slightly because of data-points in September and October 2008. However, more recent estimates have fallen back somewhat.

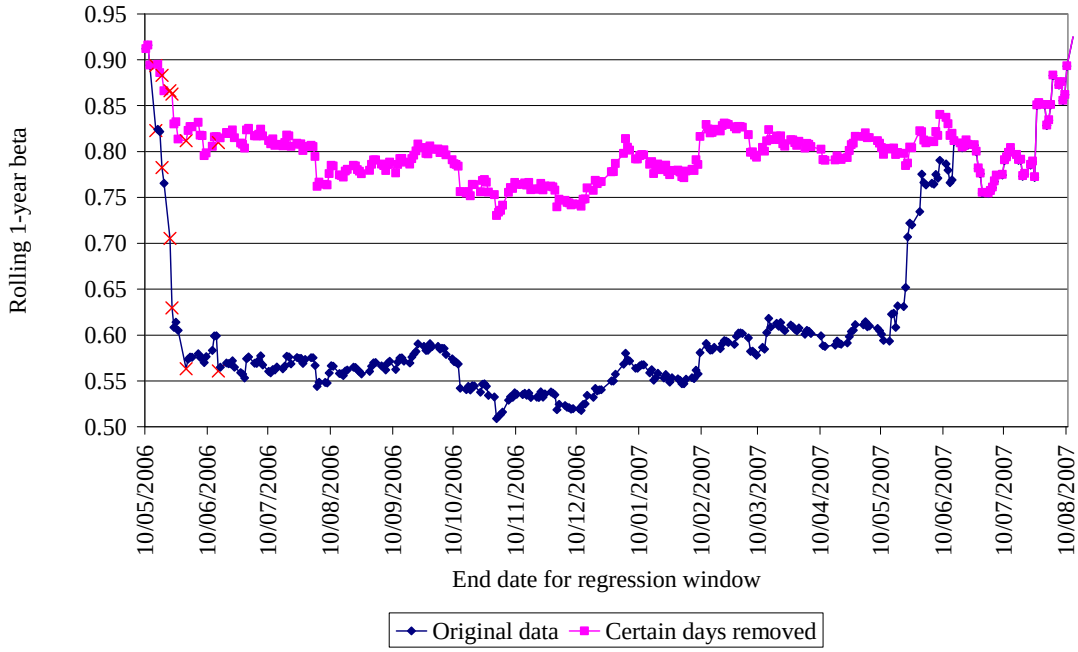
Table 11

BT beta measured against the FTSE allshare index

Start date	11/10/2006	11/10/2006	11/10/2006
End date	15/09/2008	25/09/2008	10/10/2008
Beta	0.86	0.89	0.93
Standard error	0.05	0.05	0.05

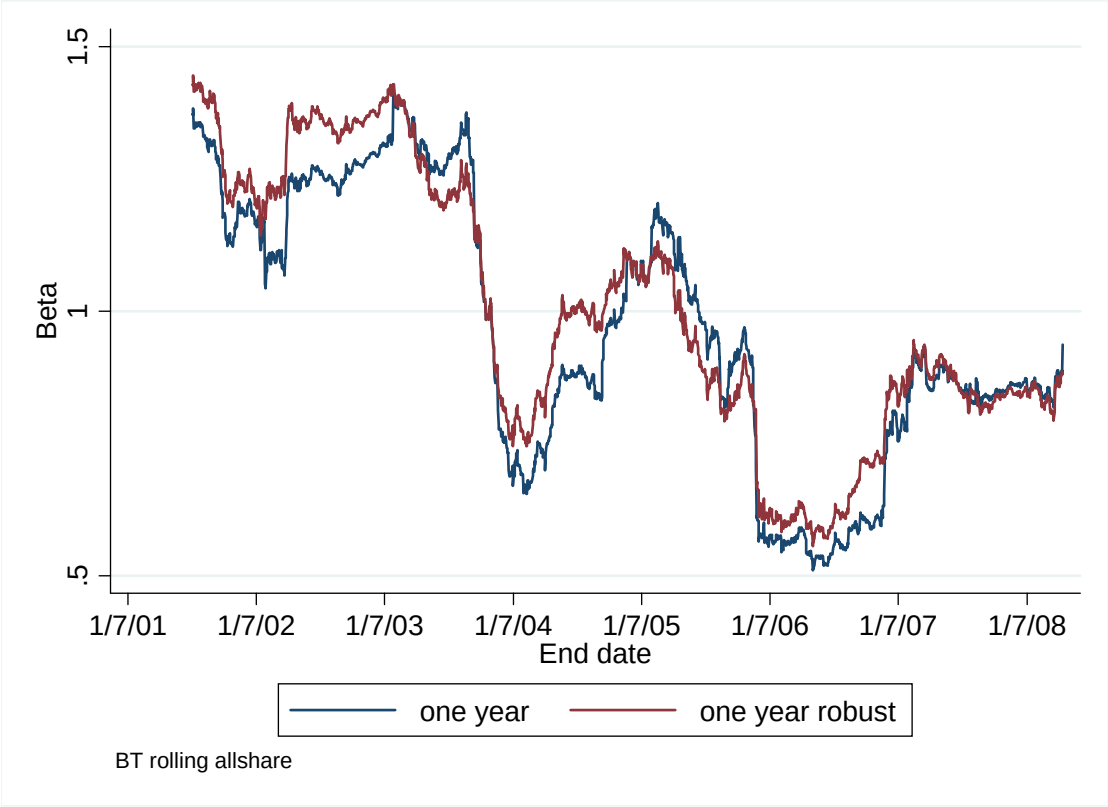
We carried out a similar analysis to determine whether influential outliers might be responsible for the dramatically reduced one-year beta estimate during late 2006 and early 2007 shown in Figure 1 above. There are six days in the second half of May and the first half of June 2006 which have a large influence on the one-year regression (May 15th, 18th, 22nd, 23rd, 30th, and June 15th). We illustrate the impact of removing these days from the regression in Figure 4 (days marked with a red cross have been removed from the regression).

Figure 4



We have also repeated the rolling regression on a "robust" basis, which removes the influence of "significant outliers" (Figure 5). Both the "robust" and the normal regression show the dramatic fall to around 0.6 in 2005/6 because, although the six days listed above are "unusual" in the sense of having a large impact on the regression results, only one of the points is a "significant outlier", in the sense of having both a significant influence on the regression result and having an unusual relationship between the BT return and the index return.

Figure 5



2.3 The Dimson adjustment

One potential mis-specification could arise from the use of daily data. As discussed in previous papers, using daily returns for beta estimation can lead to inaccurate beta estimates for a number of reasons related to issues of:

- Liquidity: using daily returns will tend to under-estimate the beta for thinly traded stocks (because "theoretical" responses to changes in the overall market value are not reflected in observed prices), and therefore to over-estimate the beta of thickly traded stocks (since beta estimation must be right on average over the whole portfolio of stocks that make up the market index).

- Non-synchronous trading: if for example an event occurs at 5pm that moves the price of BT and other firms around the world, then this will be reflected in the daily return of that day for the NYSE, but tomorrow's daily return for the BT share. Since shares traded on the NYSE make up part of the Allworld index, regression of daily BT returns against the Allworld index will miss part of the correlation.

These types of effects can be tested for and adjustments made using the "Dimson technique" of regressing against lagged and leading index returns. In the past we have found that for the Allshare index the Dimson test does not indicate a significant relationship, and no adjustment is necessary.

For the Allworld index, we have performed regressions using one lag and lead, as reported below. The Dimson beta is lower than the "standard" beta (see Table 12), as a result of the lead term. The Dimson adjustment is significantly different from zero at the 10% level of significance, but not at the 5% level (p-value of 0.9).

Given the relatively large p-values, and the ongoing turmoil in world markets, we would wish to perform further analysis before drawing strong conclusions from these findings. We note that in previous reports we have found that the Dimson adjustment was very sensitive to the choice of data window.

Table 12

Index	Allworld	Allworld
Start date	11/03/2008	11/03/2007
End date	10/03/2009	10/03/2009
Beta	0.83	0.85
Dimson beta	0.59	0.65
p-value for adjustment	0.09	0.09

3 Conclusions

Our findings suggest that:

- Based on our regressions, it is reasonable to use a range of 0.8 to 1.0 for BT's current equity beta, on the basis that this would correspond to gearing of about 38%. A forward looking estimate would be higher to reflect the new, higher gearing. However this would not change the estimated asset beta, and hence would not change a standard regulatory estimation of the equity beta, where the measured beta is de-levered and re-levered at an assumed level of gearing.
- There is some evidence to favour a lower estimate for the beta (at 38% gearing), since the observed beta has not increased despite the much higher actual gearing. However this evidence should be interpreted with care.
- The more recent estimates are somewhat affected by the impact of current market turmoil in that there are a number of "unusual" days in this part of the data window which are "influential outliers".
- We would place less reliance on the more recent estimates of equity beta (since late 2008) for which BT's gearing was changing rapidly during part of the data window.
- The lower one-year beta estimates from mid 2006 to mid 2007 seem to be due to a small number of "unusual" days.[12]

[12] The estimate falls when the unusual days enter the regression window, and rises again when they leave, explaining the U-shaped portion of the rolling regression chart centred around December 2006.

Appendix

Table 1a below corresponds to Table 1, with the addition of a "robust" standard error. The robust standard error is very similar to the normal standard error.

Table1a

BT beta measured against the FTSE allshare index

Period	1 year	2 year	5 year
Start date	11/03/2008	11/03/2007	11/03/2004
End date	10/03/2009	10/03/2009	10/03/2009
Beta	0.85	0.85	0.84
Standard error	0.07	0.05	0.03
Robust standard error	0.07	0.06	0.05

BT beta measured against the FTSE allworld index

Period	1 year	2 year	5 year
Start date	11/03/2008	11/03/2007	11/03/2004
End date	10/03/2009	10/03/2009	10/03/2009
Beta	0.83	0.85	0.84
Standard error	0.09	0.06	0.04
Robust standard error	0.11	0.09	0.05

Below we show the graphs of residuals against index returns for the Allshare index (one year regression) and the Allworld index (one year and two year regressions), corresponding to Figure 2 in the main text.

Figure 2a: BT vs Allworld two year residuals

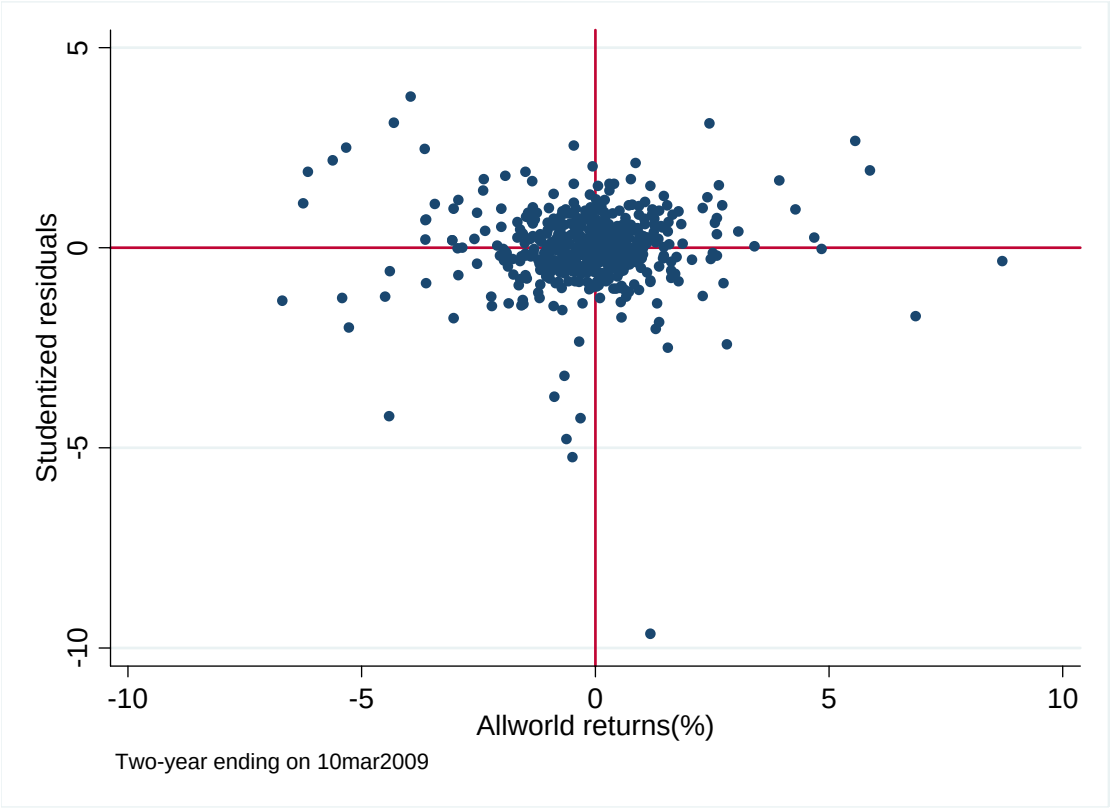


Figure 2b: BT vs Allshare one year residuals

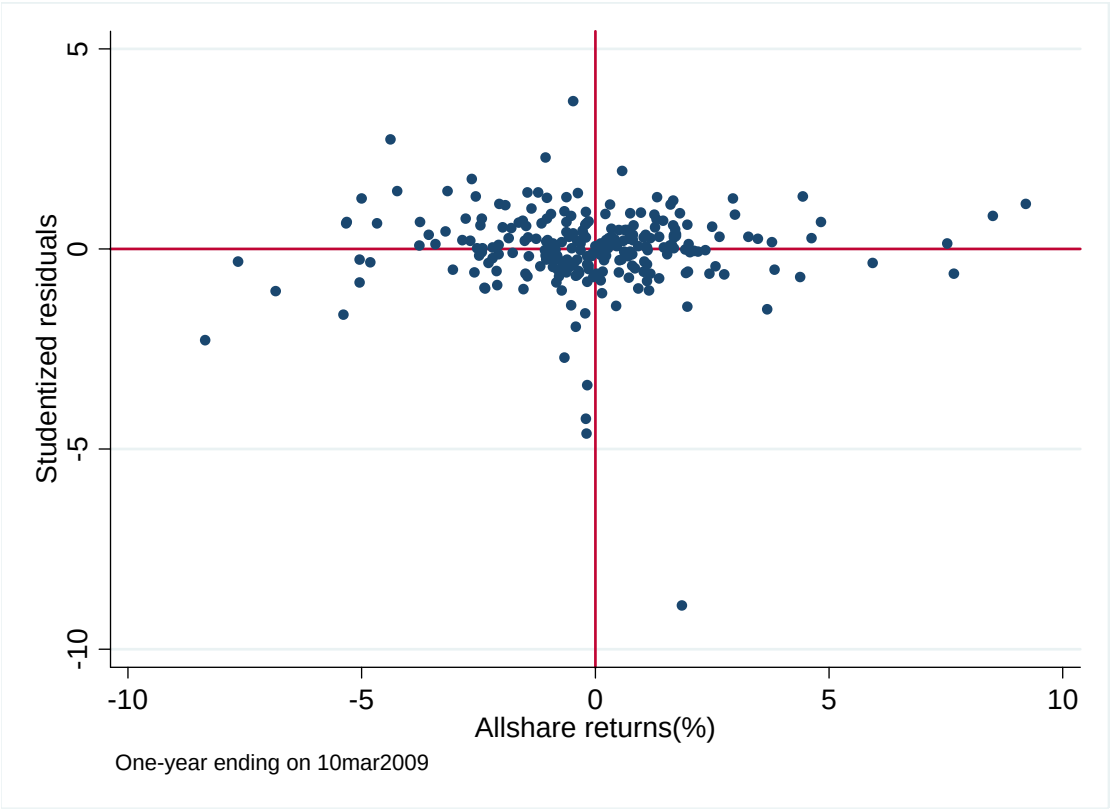
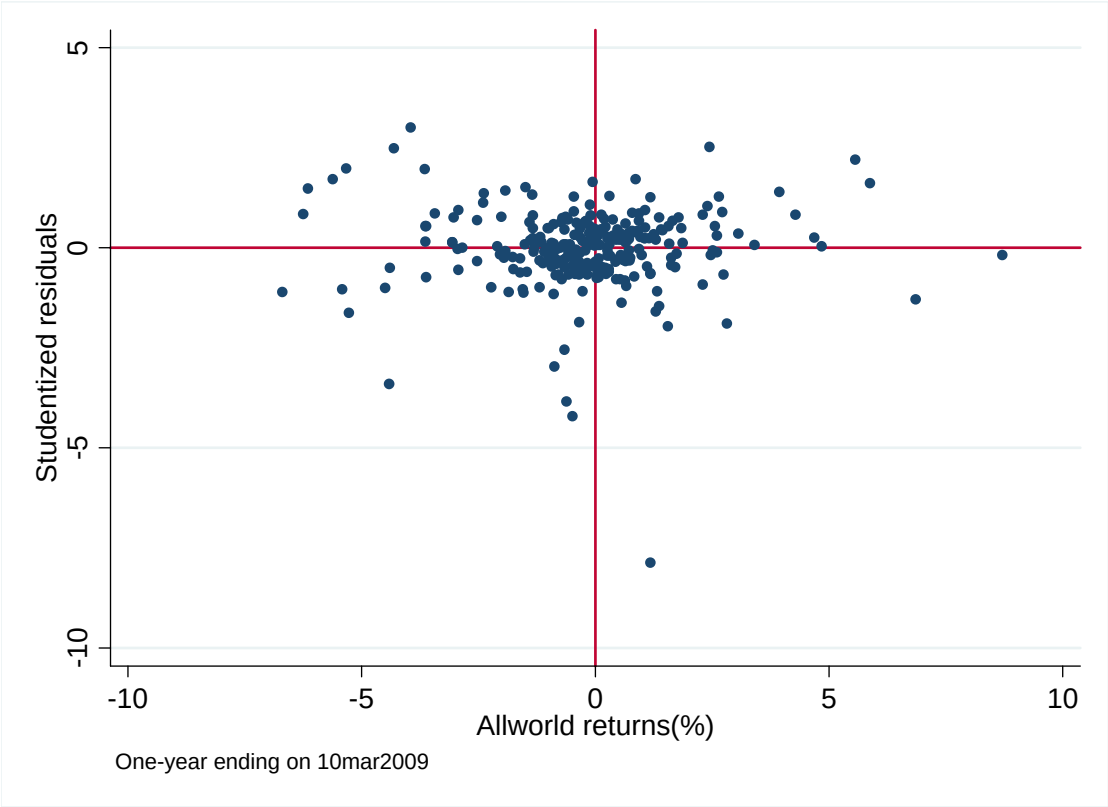


Figure 2c: BT vs Allworld one year residuals



Below we show the histogram of "studentised residuals" for the Allshare index (1 year regression) and the Allworld index (1 year and 2 year regressions), corresponding to Figure 3 in the main text.

Figure 3a: Distribution of BT vs Allshare one year studentised residuals

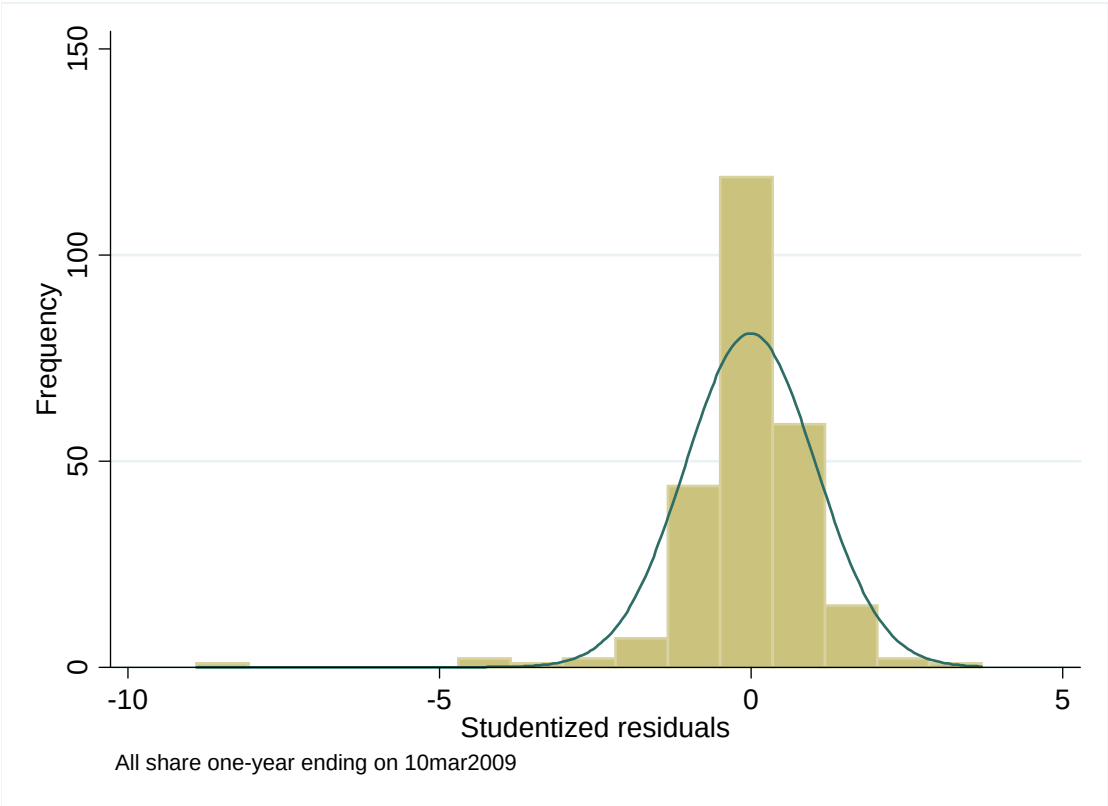


Figure 3b: Distribution of BT vs Allworld one year studentised residuals

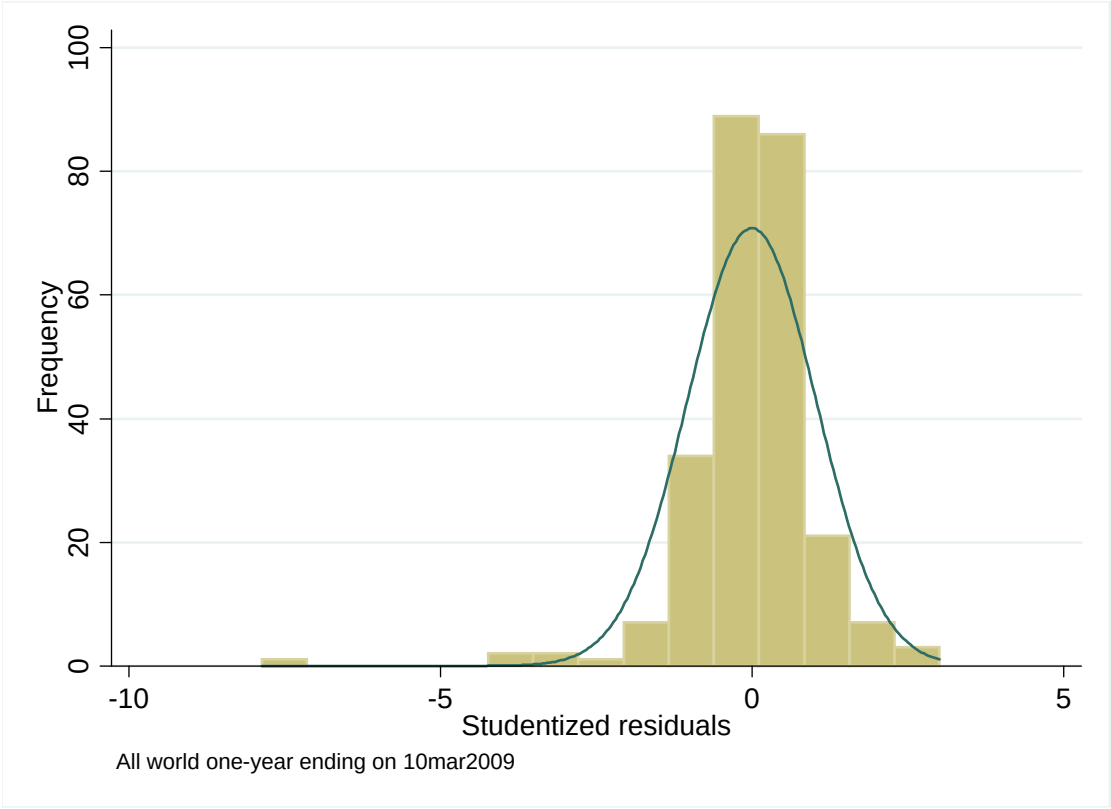


Figure 3c: Distribution of BT vs Allworld two year studentised residuals

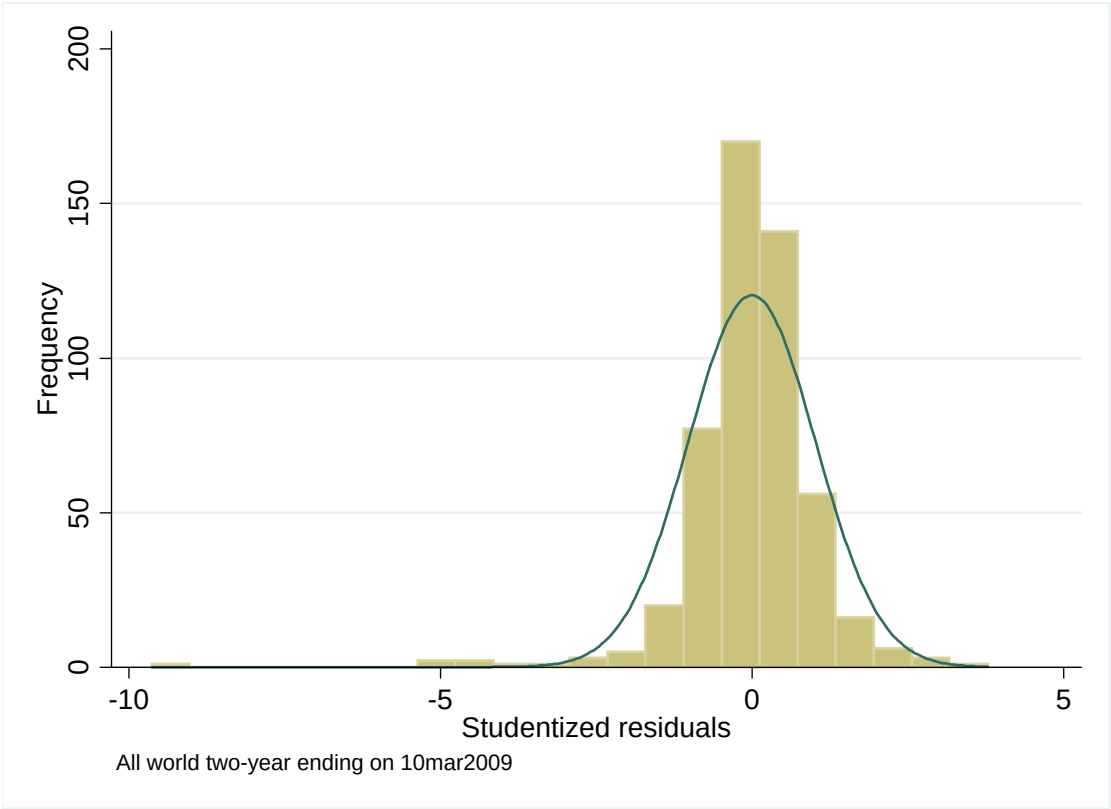


Figure 1a: Allworld beta "rolling estimates"