Updated Estimate of

BT's Equity BETA

Number 4th 2008

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Contents

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 March 2008 report, and includes data up to and including October 10th 2008. 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

BT beta measured against the FTSE allshare index

Period	1 year	2 year	5 year
Start date	11/10/2007	11/10/2006	11/10/2003
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.94	0.93	0.88
Standard error	0.07	0.05	0.04

BT beta measured against the FTSE allworld index

Period	1 year	2 year	5 year
Start date	11/10/2007	11/10/2006	11/10/2003
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.96	0.97	0.89
Standard error	0.10	0.07	0.05

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

BT beta measured against the FTSE allshare index

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

BT beta measured against the FTSE allworld index

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

The most recent one- and two-year all-share betas are about 0.1 higher than in March 2008. 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 increase 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 increase 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 was fairly constant until the beginning of 2007, it has subsequently risen (indeed almost doubled) as a result of falls in BT's share price.[1] We can partially remove the effect of changes in gearing by "re-levering" the estimates[2] in Table 2 to constant gearing.[3] The results are shown in Table 3.

Table 3

BT beta measured against the FTSE allshare index

Period	1 year	1 year	1 year	**1 year**
End date	28/02/2006	28/02/2007	29/02/2008	**10/10/2008**
Measured beta	0.82	0.60	0.84	**0.94**
Historic gearing	32%	25%	30%	**38%**
Relevered beta	1.07	0.87	1.13	**1.12**

BT beta measured against the FTSE allworld index

Period	1 year	1 year	1 year	**1 year**
End date	28/02/2006	28/02/2007	29/02/2008	**10/10/2008**
Measured beta	0.64	0.67	0.95	**0.96**
Historic gearing	32%	25%	30%	**38%**
Relevered beta	0.84	0.97	1.28	**1.14**

Notes
Historic 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
48% and a debt beta of zero.

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[1] Gearing in the four quarters starting 31st March 2006 averaged 27% on a net debt basis, and 26% in the four quarters starting 31st March 2007. However, during 2008 gearing has risen to approximately 48%).

[2] For example, the re-levered beta of 1.07 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 48% 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.

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Although the analysis is rather crude, the figures in Table 3 suggest that recent increases in BT's estimated equity beta against the Allshare index may be due to changes in gearing. Note in particular that with constant gearing, the estimate against the Allshare is almost unchanged (1.13 vs 1.12) between the estimates ending 29/2/08 and 10/10/08, while against the Allworld it actually falls from 1.28 to 1.14.

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.[4] 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 very recent data, i.e., the dramatic price movements of recent weeks (although the dataset ends on Oct 10), which has caused the estimates to rise in the last few days of the data window.

Figure 1

BT rolling allshare
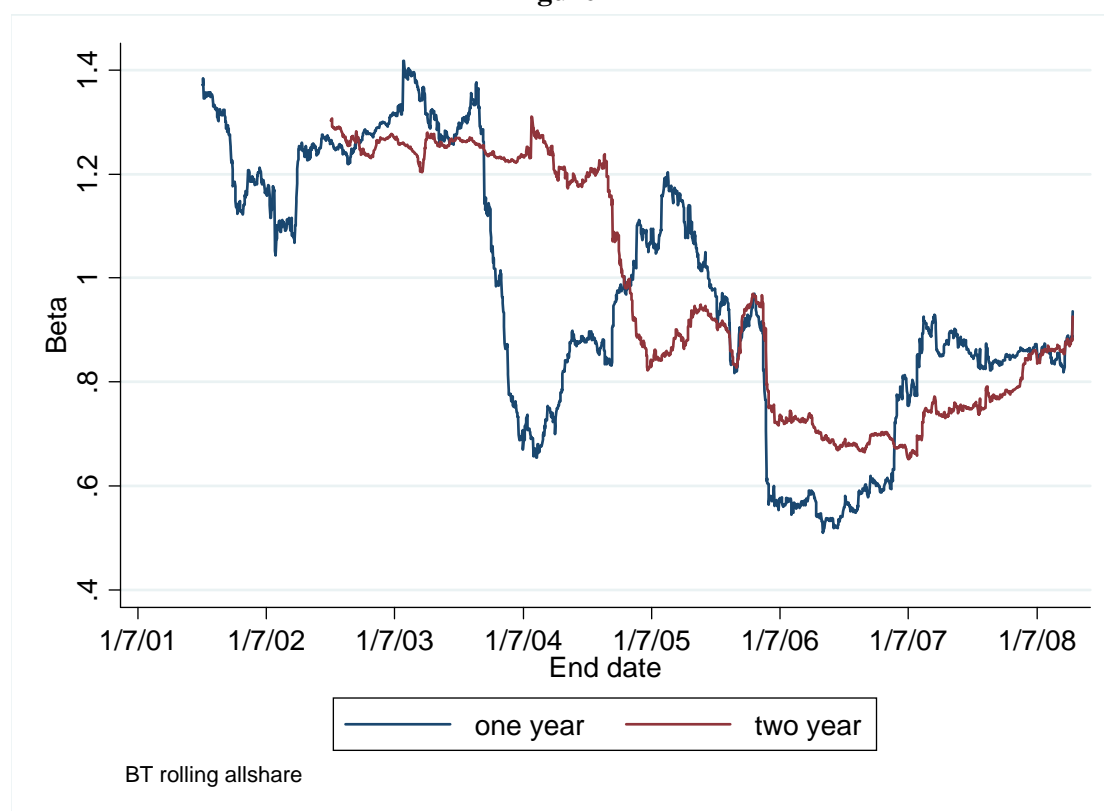
A natural question is whether these unusual days are "outliers" that should be eliminated. In terms of finance theory, we are not aware of a clear argument for

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[3] This is only a partial correction because we continue to assume implicitly that gearing does not change during the beta estimation window.

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

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 recent market volatility may mean that the most 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".[5] Table 4 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).

Table 4

Regression	Normal	Influential outliers removed	'Robust'
Start date	11/10/2007	11/10/2007	11/10/2007
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.94	0.89	0.89
Standard error	0.07	0.05	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:

- BT's estimated equity beta has risen slightly during 2008, although it remains somewhat lower than in 2004/05.

- This increase in beta against the Allshare index probably reflects the much higher level of gearing following the coincident fall in BT's share price.

- The lower one-year beta estimates from mid 2006 to mid 2007 seem to be due to a small number of "unusual" days.[6]

- The most 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".

- Based on our regressions, it is reasonable to use a range of 0.8 to 1.0 for BT's current equity beta. A forward looking estimate would be higher to reflect the

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[5] 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.

[6] 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.

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.

BT's comments

BT commented on our March report in its response to Ofcom's consultation document. BT stated that recent estimates of its beta were higher than those that would have been made in 2006. We agree with this statement, which is supported by Figure 1 and Table 2, although we noted above the methodological difficulties associated with assuming that the underlying beta might be changing over time. BT also implied that the fact that recent estimates are above those in 2006 should result in a "forward-looking" estimate of its beta above current estimates, on the grounds that the "trend" in beta might continue. As noted above, we agree with BT that a forward-looking beta should be higher, because of the recent increase in gearing. However, as also noted above, in a standard regulatory context this would be irrelevant because regulatory practice is to "re-lever" the measured equity beta to a notional gearing level. The impact of increasing equity beta and increasing gearing would net out.

BT also commented that there are theoretical reasons for believing that beta will regress to unity over time. We agree that there is an argument for adopting a Bayesian approach, starting from a prior assumption that beta is one (for example) and modifying this assumption in light of the measured beta. This method results in a beta estimate part way between the measured figure and the prior assumption. However, with beta estimates using daily (rather than monthly) returns, the standard errors are small and this adjustment is therefore insignificant.[7]

We are also aware of some empirical evidence that portfolio betas have tended, on average, towards one over time, but we are not aware of "good theoretical reasons" why this should be so.[8]

We agree that the BT equity beta as estimated against a world index is higher than when measured against the UK index, using the most recent data.

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[7] Vasicek, O. A., *Journal of Finance* 28 (1973) 1233–1239.

[8] See discussion in Lally, M., *The Financial Review*, 33 (1988) 183–198.

2 Statistical Reliability

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:

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.

2.1 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

Two-year ending on 10oct2008
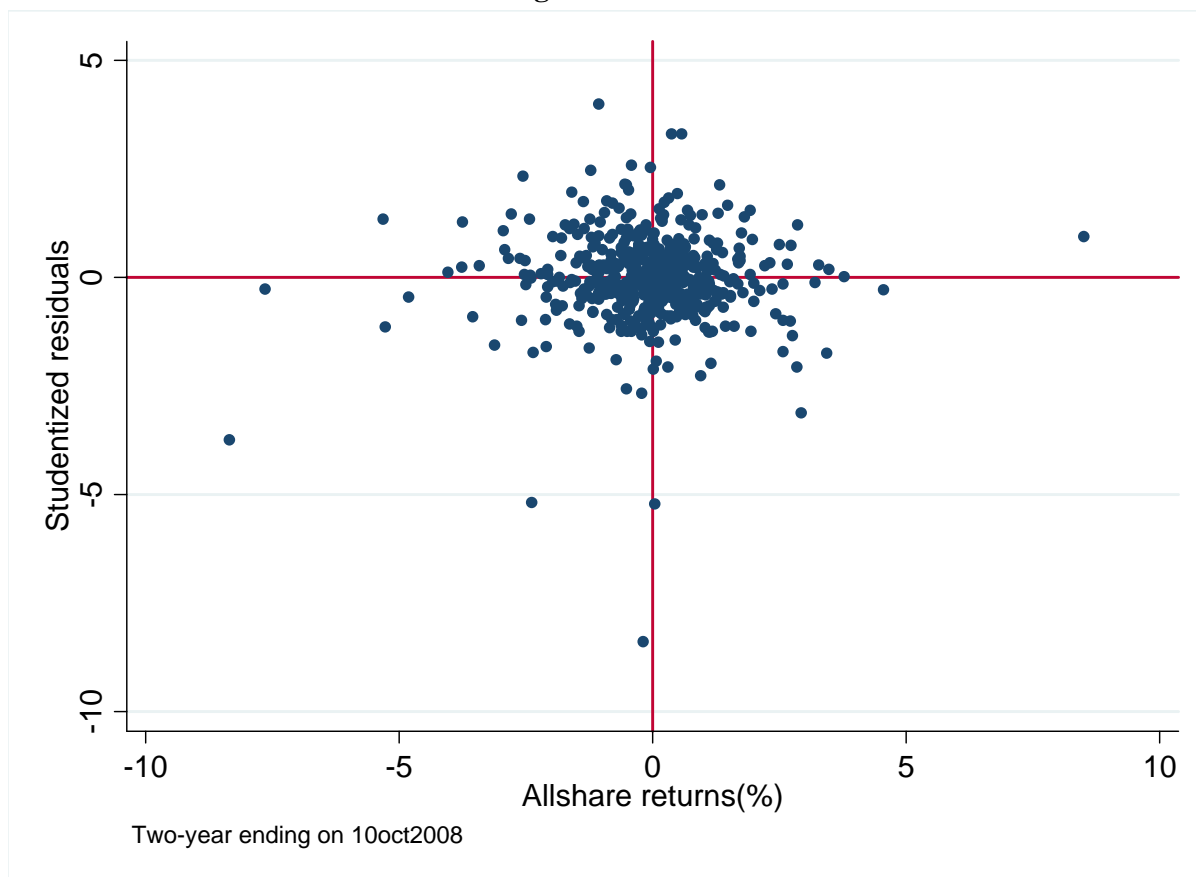
Although Figure 2 does not show any obvious evidence of heteroscedasticity, we have also performed formal tests (the White test) for heteroscedasticity, reported in Table 5 below. The White test suggests that regressions against the Allworld index show evidence of heteroscedasticity (possibly as a result of the recent volatility in market returns associated with the "credit crunch"). 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 5

BT beta measured against the FTSE allshare index

Index	Allshare	Allworld	Allshare	Allworld
Start date	11/10/2006	11/10/2006	11/10/2007	11/10/2007
End date	10/10/2008	10/10/2008	10/10/2008	10/10/2008
White statistic	0.44	28.11	1.33	12.02
p-value	0.11	0.00	0.52	0.00

2.2 Tests for auto-correlation

We have performed a formal test (the Durbin-Watson test) for auto-correlation, reported in Table 6 below. The test shows no sign of auto-correlation.[9]

Table 6

Index	Allshare	Allworld	Allshare	Allworld
Start date	11/10/2006	11/10/2006	11/10/2007	11/10/2007
End date	10/10/2008	10/10/2008	10/10/2008	10/10/2008
d-stat	1.93	2.20	1.93	2.22

2.3 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.

Figure 3

Allshare two-year ending on 10oct2008

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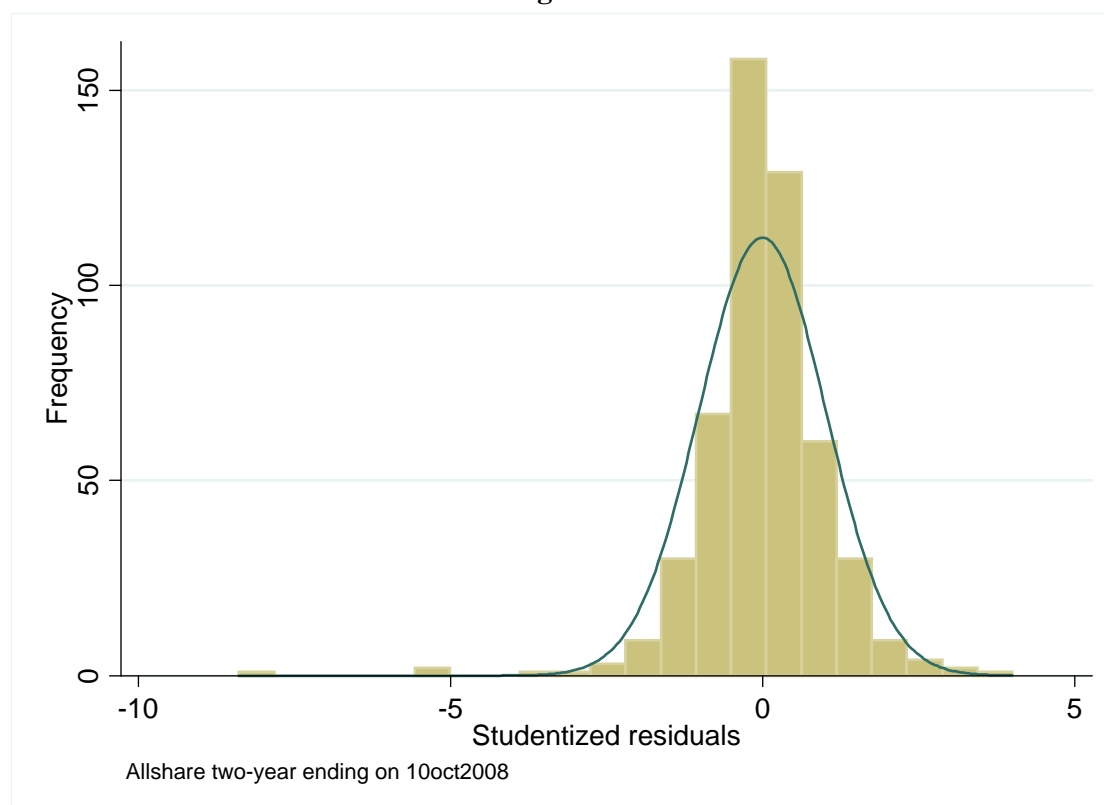
[9] Auto-correlation would be signalled by a statistic outside the range 1.65 to 2.31.

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 7 lists the observations with D scores over this threshold and which have studentized residuals of more than +/- 3. We identify the six observations shown in bold as influential outliers.[10]

Table 7

Date	BT return (%)	Allshare return (%)	Cook's D	Residuals
08/01/2008	5.21	0.37	0.012	3.32
22/01/2008	**-1.94**	**2.93**	**0.053**	**-3.12**
07/02/2008	**-9.80**	**-2.39**	**0.094**	**-5.17**
15/05/2008	5.38	0.57	0.013	3.31
31/07/2008	**-11.99**	**-0.18**	**0.062**	**-8.39**
21/08/2008	**-7.63**	**0.04**	**0.026**	**-5.21**
09/10/2008	**4.86**	**-1.07**	**0.023**	**4.00**
10/10/2008	**-13.11**	**-8.34**	**0.512**	**-3.74**

We recalculate the two-year Allshare regression excluding the influential outliers shown in bold in Table 7. The results are reported in Table 8, and the same table also shows the results of a 'robust' regression that assigns lower weight to outliers than OLS does. Table 4 above shows equivalent results for the one-year regression. Neither estimate is significantly affected by the outliers. Nevertheless, we note that two of the outliers are from the last few days of the data window, during a period of extreme swings in prices in world financial markets.

Table 8

BT beta measured against the FTSE allshare index

Regression	Normal	Influential outliers removed	'Robust'
Start date	11/10/2006	11/10/2006	11/10/2006
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.93	0.88	0.89
Standard error	0.05	0.04	0.04

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[10] The other two points are not excluded because it is only slightly above each threshold, whereas the other six are a long way above one or both thresholds.

We investigated further the possible impact of recent financial turmoil by re-estimating beta excluding the most recent data. Table 9 shows that the estimated beta rises slightly because of data-points in the last few weeks.

Table 9

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 recalculate the two-year Allshare regression excluding the influential outliers shown in bold in Table 7. The results are reported in Table 8, and the same table also shows the results of a 'robust' regression that assigns lower weight to outliers than OLS does. Table 4 above shows equivalent results for the one-year regression. Neither estimate is significantly affected by the outliers. Nevertheless, we note that two of the outliers are from the last few days of the data window, during a period of extreme swings in prices in world financial markets.

Table 10

BT beta measured against the FTSE allshare index

| Regression	Normal	Influential outliers removed	'Robust'
Start date	11/10/2006	11/10/2006	11/10/2006
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.93	0.88	0.89
Standard error	0.05	0.04	0.04

We investigated further the possible impact of recent financial turmoil by re-estimating beta excluding the most recent data. Table 9 shows that the estimated beta rises slightly because of data-points in the last few weeks.

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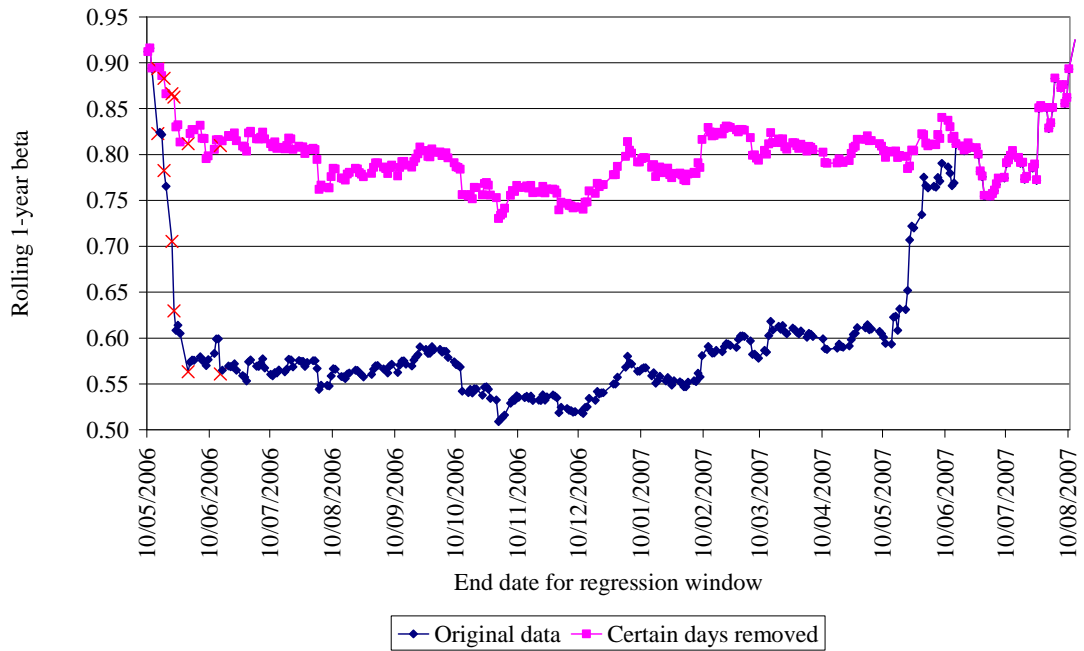
We have also repeated the rolling regression on a "robust" basis, which removes the influence of "significant outliers" (Figure 5). Both the "robust" and the normal regression show the dramatic fall to around 0.6 in 2005/6 because, although the six days listed above are "unusual" in the sense of having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

Figure 5

BT rolling allshare
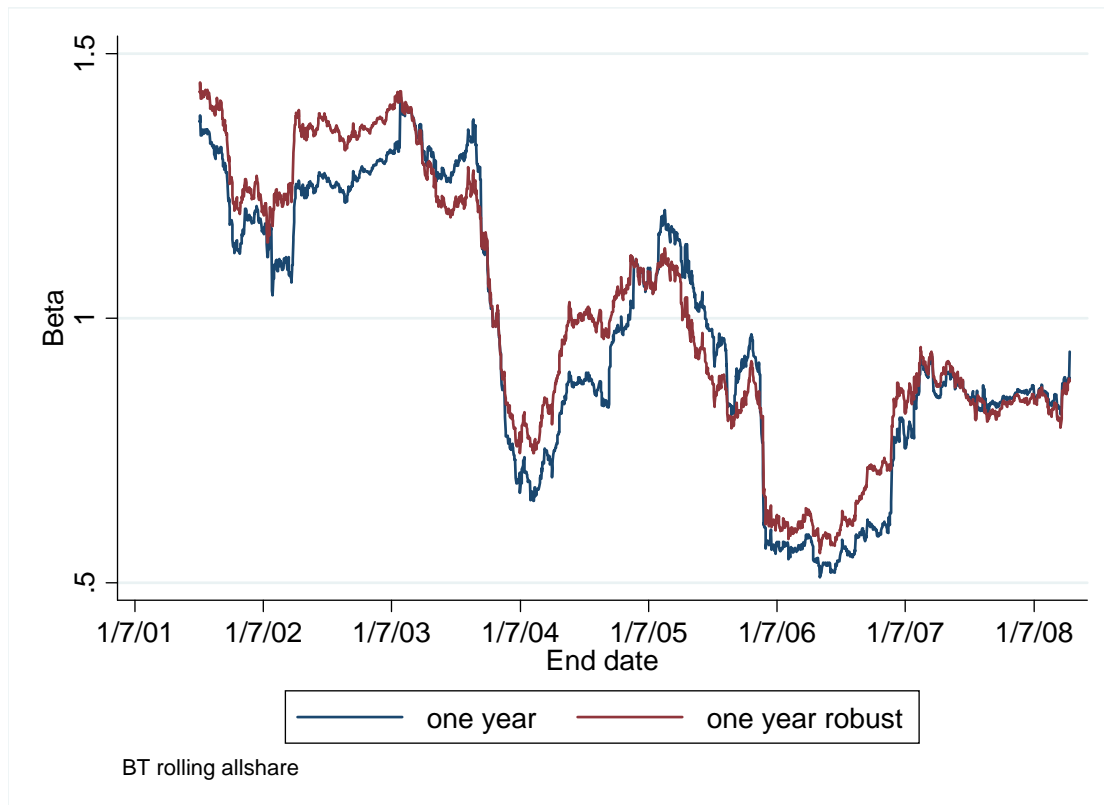
2.4 The Dimson adjustment

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 co-efficient on the lead term is significant, and the Dimson beta is as a result lower than the "standard" beta (see Table 12). However, we suspect that this result may be spurious: when we repeat the Dimson test excluding the last few weeks from the dataset, the Dimson beta is much closer to the standard beta (see Table 13).

Table 12

Dimson regression

Index	Allworld	Allworld
Start date	11/10/2007	11/10/2006
End date	10/10/2008	10/10/2008
Allworld lag co-efficient	-0.02	-0.04
Allworld lag p-value	0.81	0.61
Allworld lead co-efficient	-0.23	-0.20
Allworld lead p-value	0.02	0.00
Dimson beta	0.65	0.77

Table 13

Dimson regression

Index	Allworld	Allworld
Start date	11/10/2007	11/10/2006
End date	25/09/2008	25/09/2008
Dimson beta	0.87	0.87

3 Conclusions

Our findings suggest that:

- BT's estimated equity beta has risen slightly during 2008, although it remains somewhat lower than in 2004/05.

- This increase in beta against the Allshare index probably reflects the much higher level of gearing following the coincident fall in BT's share price.

- The lower one-year beta estimates from mid 2006 to mid 2007 seem to be due to a small number of "unusual" days.[11]

- The most 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".

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[11] 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.

- Based on our regressions, it is reasonable to use a range of 0.8 to 1.0 for BT's current equity beta. 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.

Appendix

Tables 1a and 2a below correspond to Tables 1 and 2 in the main text, 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	11/10/2007	11/10/2006	11/10/2003
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.94	0.93	0.88
Standard error	0.07	0.05	0.04
Robust standard error	0.08	0.06	0.05

BT beta measured against the FTSE allworld index

Period	1 year	2 year	5 year
Start date	11/10/2007	11/10/2006	11/10/2003
End date	10/10/2008	10/10/2008	10/10/2008
Beta	0.96	0.97	0.89
Standard error	0.10	0.07	0.05
Robust standard error	0.15	0.12	0.09

Table2a

BT beta measured against the FTSE allshare index

Period	1 year	1 year	1 year	1 year	2 years	2 years	2 years	2 years
Start date	01/03/2005	01/03/2006	01/03/2007	11/10/2007	28/02/2004	01/03/2005	01/03/2006	11/10/2006
End date	28/02/2006	28/02/2007	29/02/2008	10/10/2008	28/02/2006	28/02/2007	29/02/2008	10/10/2008
Beta	0.82	0.60	0.84	0.94	0.83	0.67	0.78	0.93
Standard error	0.12	0.10	0.06	0.07	0.08	0.08	0.05	0.05
Robust standard error	0.13	0.11	0.09	0.08	0.09	0.08	0.07	0.06

BT beta measured against the FTSE allworld index

Period	1 year	1 year	1 year	1 year	2 years	2 years	2 years	2 years
Start date	01/03/2005	01/03/2006	01/03/2007	11/10/2007	28/02/2004	01/03/2005	01/03/2006	11/10/2006
End date	28/02/2006	28/02/2007	29/02/2008	10/10/2008	28/02/2006	28/02/2007	29/02/2008	10/10/2008
Beta	0.64	0.67	0.95	0.96	0.73	0.65	0.87	0.97
Standard error	0.15	0.14	0.10	0.10	0.09	0.10	0.08	0.07
Robust standard error	0.16	0.16	0.11	0.15	0.10	0.11	0.09	0.12

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.

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Figure 2a: BT vs Allworld two year residuals

Two-year ending on 10oct2008
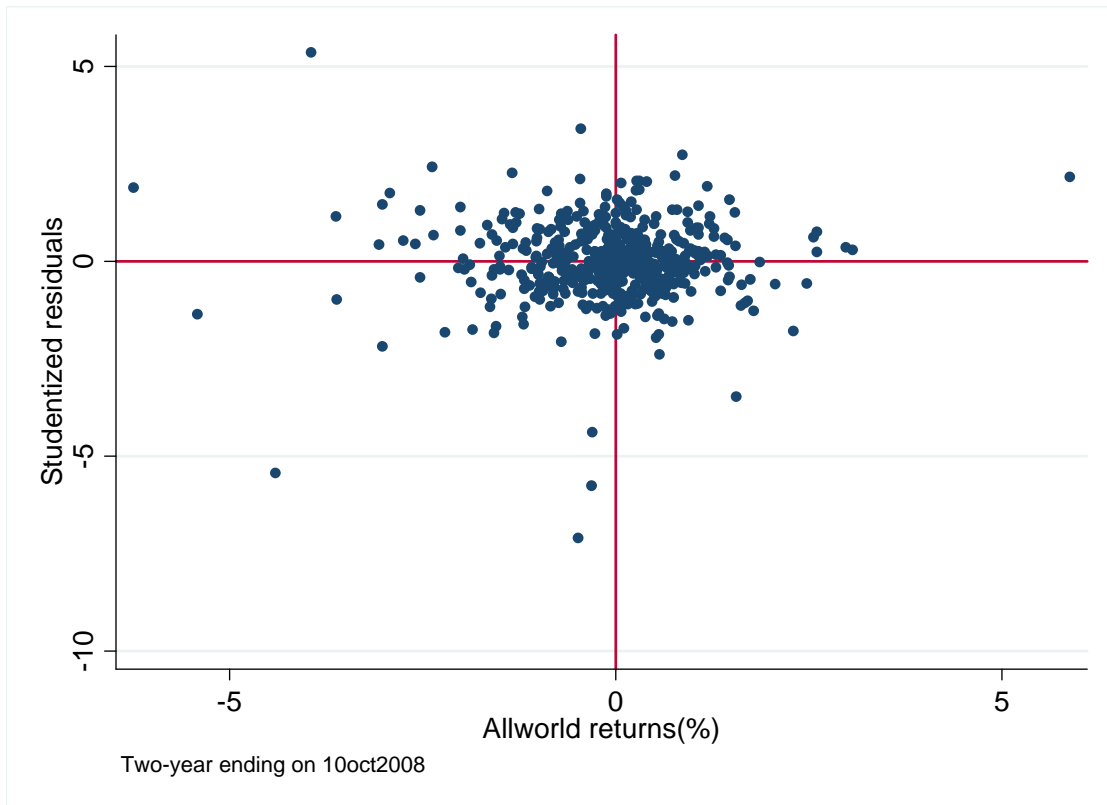
Figure 2b: BT vs Allshare one year residuals

One-year ending on 10oct2008
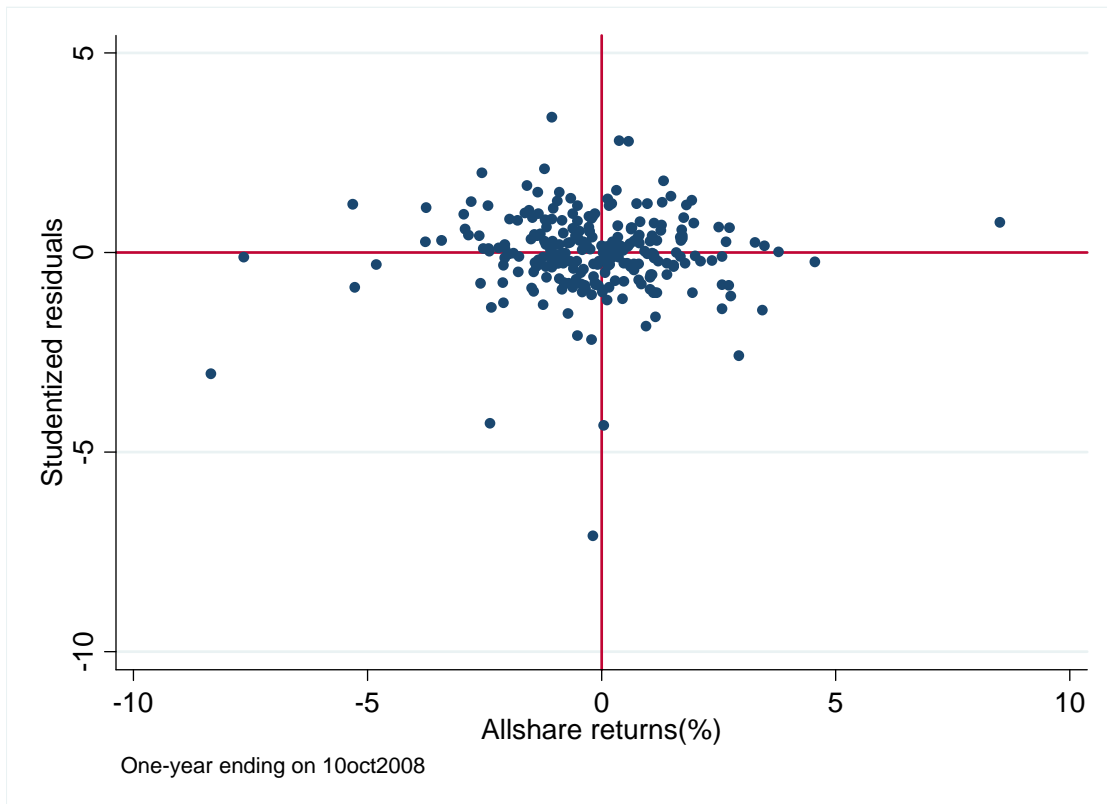
Figure 2c: BT vs Allworld one year residuals


One-year ending on 10oct2008
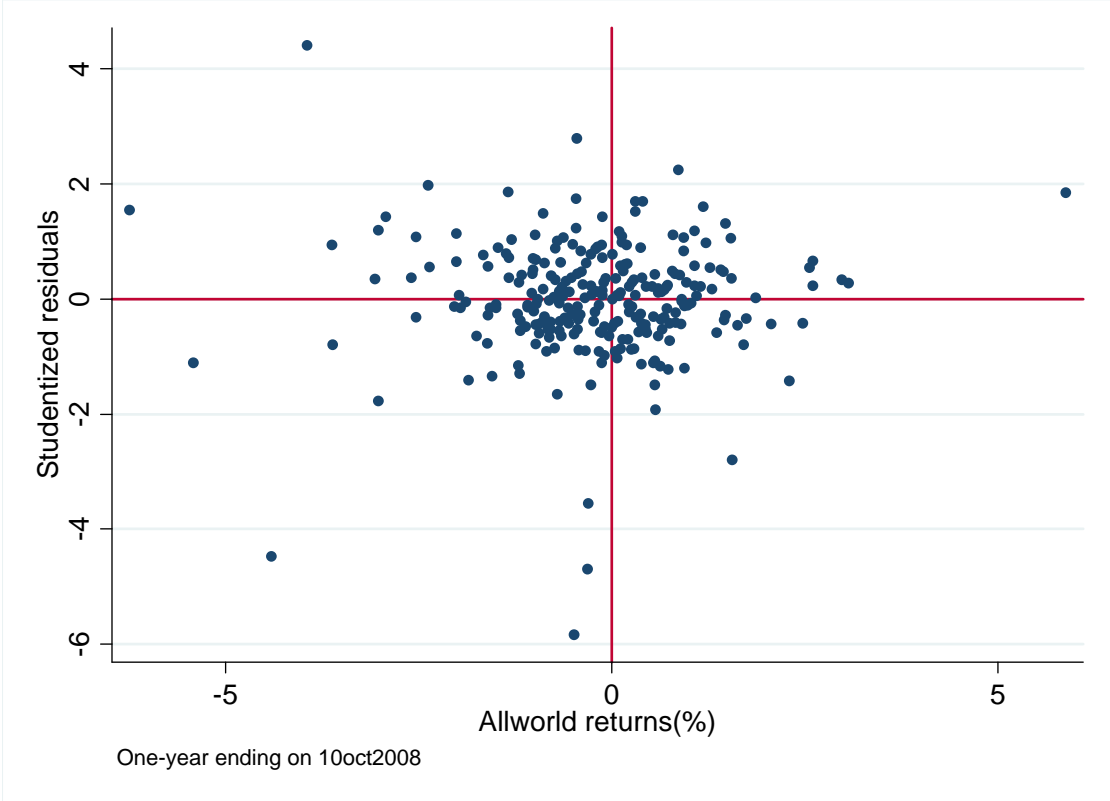
Below we show the histogram of "studentised residuals" for the Allshare index (1 year regression) and the Allworld index (1 year and 2 year regressions), corresponding to Figure 3 in the main text.
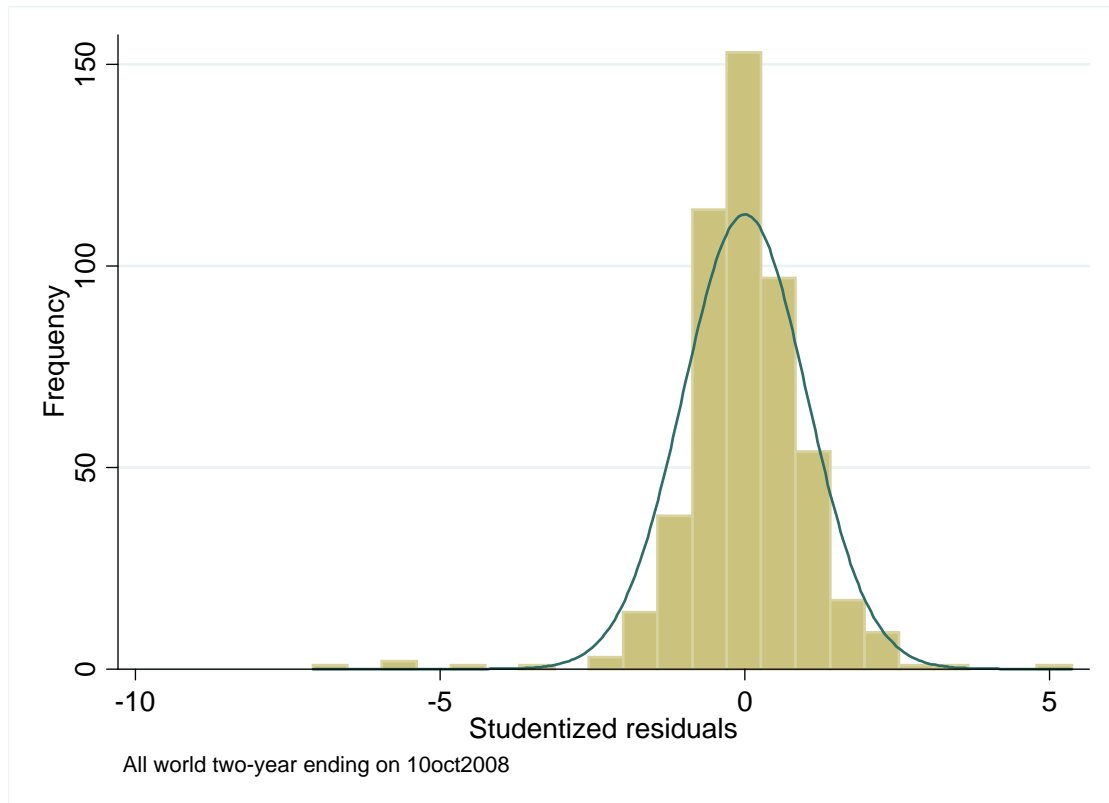
Figure 3a: Distribution of BT vs Allshare one year studentised residuals

All share one-year ending on 10oct2008
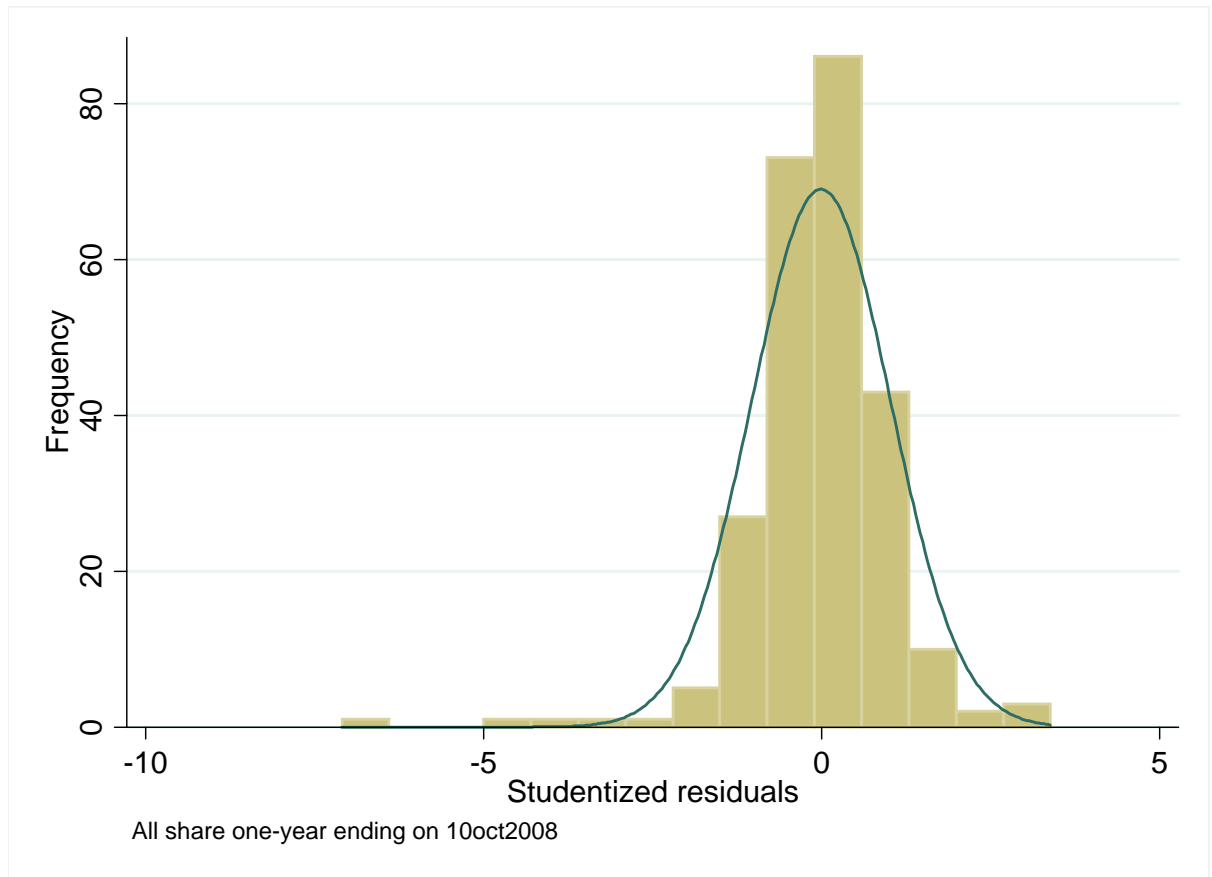
Figure 3b: Distribution of BT vs Allworld one year studentised residuals

All world one-year ending on 10oct2008

20
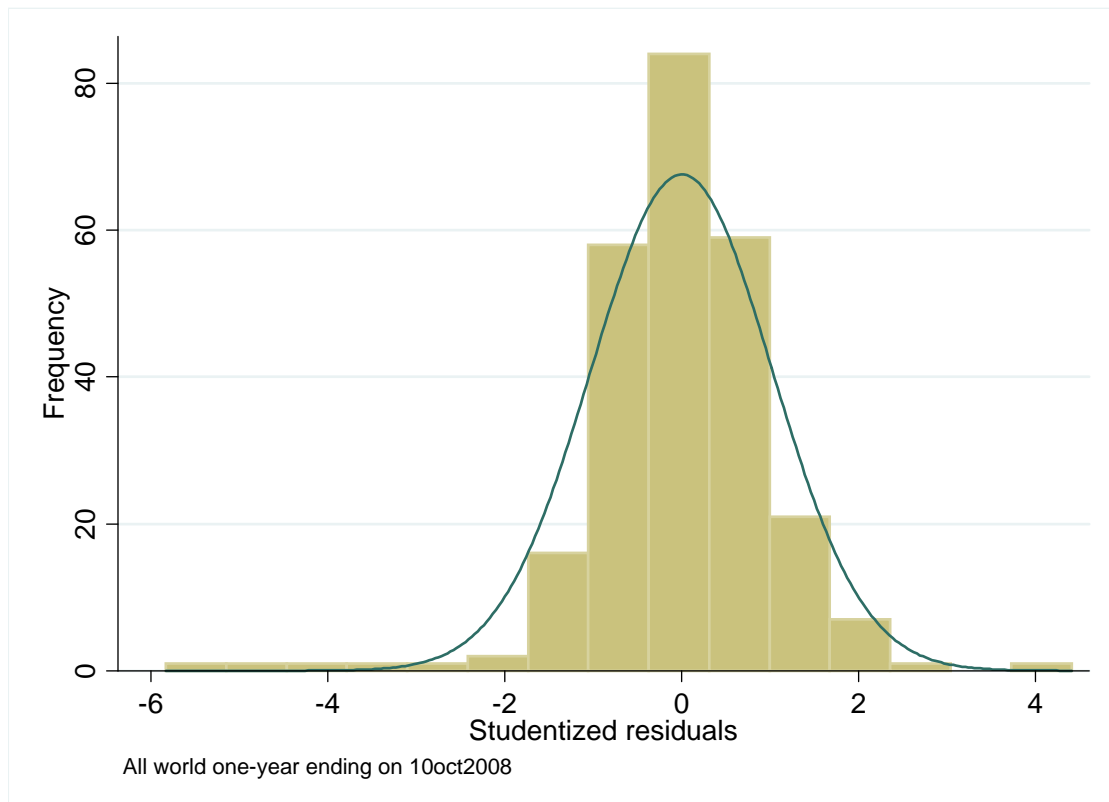
Figure 3c: Distribution of BT vs Allworld two year studentised residuals

All world two-year ending on 10oct2008

Figure 1a: Allworld beta "rolling estimates"

BT rolling allworld