ESTIMATE OF EQUITY BETA

FOR UK MOBILE OWNERS

DECEMBER 2009

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Contents

1 Introduction

Ofcom has asked us to estimate the equity betas for the parent companies of the four UK mobile phone networks: Vodafone, Telefonica, France Telecom and Deutsche Telekom. We understand that Ofcom intends to use these estimates to inform its decision on the level of UK mobile call termination charges. We perform various analyses and present beta estimates for the four parent companies. Two important caveats apply:

1. None of the four UK mobile operators has a dedicated tracking stock. The closest available stock market data relates to the four parent companies and those companies engage in a diverse range of telecoms and IT activities in addition to UK mobile. Without further analysis, it remains unclear the extent to which the observed betas for the parent companies reflect the particular risks associated with UK mobile or the risks associated with the parent companies' other activities.

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

In this report, we adopt the same methodology as in other previous engagements for Ofcom.[1] We calculate daily returns from holding stock in the four parent companies and from holding a market index. We examine data for three market indices: the FTSE All-Share reflecting all stocks trading on the London Stock Exchange, the FTSE All-World reflecting a large proportion of publicly traded stocks around the world, and the FTSE All-EU reflecting the EU portion of the FTSE All-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 November 21st 2009.

Previous work for Ofcom examined beta estimation methods.[2] 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 four of the major telecoms stocks 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.

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

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

Chapter 2 presents beta estimates for the four companies. Chapter 3 reports the results of several tests of the statistical reliability of the beta estimates.

2 Equity beta estimates

2.1 Up-to-date estimates

Table 1 reports up-to-date beta estimates for the four parent companies. 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 three market indices. All of the various estimates reflect data up to November 21st 2009.

Table 1: Up-to-date beta estimates

	1 Yr				2 Yr			
	Beta	SE	Low	High	Beta	SE	Low	High
Vodafone								
All-Share	0.77	0.07	0.64	0.90	0.84	0.04	0.76	0.92
All-World	0.52	0.08	0.35	0.68	0.66	0.06	0.54	0.78
All-EU	0.56	0.06	0.44	0.68	0.71	0.04	0.63	0.80
Telefonica								
All-Share	0.47	0.04	0.40	0.54	0.67	0.03	0.61	0.72
All-World	0.48	0.05	0.38	0.58	0.64	0.04	0.56	0.73
All-EU	0.53	0.04	0.46	0.60	0.72	0.03	0.67	0.77
France Telecom								
All-Share	0.35	0.05	0.25	0.44	0.51	0.03	0.45	0.58
All-World	0.40	0.06	0.27	0.52	0.55	0.05	0.46	0.64
All-EU	0.41	0.05	0.32	0.50	0.57	0.03	0.50	0.63
Deutsche Telekom								
All-Share	0.46	0.05	0.36	0.57	0.62	0.04	0.54	0.69
All-World	0.54	0.07	0.40	0.67	0.69	0.05	0.58	0.79
All-EU	0.48	0.05	0.38	0.59	0.64	0.04	0.56	0.72
Simple Average Across Companies								
All-Share	0.51				0.66			
All-World	0.48				0.64			
All-EU	0.50				0.66			

One unsurprising characteristic of the estimates is that there appear to be slight differences between the betas against the three different market indices. For example, Telefonica, France Telecom and Deutsche Telekom all report slightly lower betas against the FTSE All-Share than betas against the two other indices. We might expect this result in part because these companies earn the majority of cash flow outside the UK. However, none of the differences between the beta estimates calculated against different indices are statistically meaningful.

There is one exception: Vodafone. It displays higher betas versus the FTSE All-Share than all the other indices. There seems a clear explanation for this phenomenon. Vodafone represents as much as 5% of the All-Share by market capitalisation.[3] This means that Vodafone's performance contributes materially to the overall performance of the FTSE All-Share. As a result, we expect to find a higher regression coefficient against the All-Share than against other indices to which Vodafone does not contribute so highly. A

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[3] According to the latest LBS Risk Measurement Service publication, Vodafone's average market capitalisation was close to £74 bn, while the overall market capitalisation of the FTSE All-Share was £1,627 bn.

simple calculation reveals that the scale of Vodafone's contribution to the FTSE All-Share could result in an additional 0.2-0.3 to the observed beta.[4] This premium does not reflect additional financial risk, just the relative magnitudes of Vodafone and the UK stock market.

A second characteristic of the beta estimates is that the two-year betas come in a bit higher than the one-year estimates. This feature is universal across both companies and indices. As we will see from subsequent graphs, this may reflect a recent downward movement in the one-year estimates, from which the two-year estimates have been so far largely immune.

A third characteristic is that there is relatively little spread in the equity beta estimates across the four companies. For example, against the FTSE All-World, the two-year betas for all four companies fall within a range of 0.14 (0.55-0.69). Again, the only exception is the beta estimate for Vodafone calculated against the FTSE All-Share. And again, the obvious explanation is Vodafone's large share of the FTSE All-Share by market capitalisation.

2.2 Beta estimates over time

Financial markets saw unusual volatility during the heart of the credit crisis. Many stock prices and indices fell dramatically and several major financial institutions experienced financial distress. We test whether these unusual conditions seriously affected equity betas. We compare the estimates in Table 1 with the results of a second set of regressions, using data just prior to the collapse of Lehman Brothers in September 2008. Table 2 shows the results.

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[4] Imagine that daily stock returns for Vodafone and the rest of the market were normally distributed. We use the random number generator in excel to generate 250 random separate daily return draws for the market. We then construct the return for Vodafone as an assumed beta times the market return plus a randomised error term. We assume that the error term is normally distributed and the magnitude of the errors corresponds with the variance of Vodafone's historic returns. We construct a third randomised return series by combining the randomised return series for Vodafone with that for the rest of the market. We give the randomised Vodafone series the weight of 0.05 and the randomised series for the rest of the market the weight 0.95. The weights correspond with Vodafone's share of the FTSE All-Share by market capitalisation. We are now able to examine the relationship between the randomised Vodafone return series and the randomised return series for the rest of the market, and then to repeat the exercise for the randomised Vodafone return series and the third series constructed to look like the FTSE All-Share including Vodafone's contribution by market capitalisation. The beta verses the FTSE All-Share reconstruction comes in roughly 0.2 and 0.3 higher than that verses the rest of the market excluding Vodafone.

Table 2: Beta estimates pre and post Lehman collapse

| | 1 Yr | | | | 2 Yr | | | |
| | Pre-Lehman | | Up-to-date | | Pre-Lehman | | Up-to-date | |
	Beta	SE	Low	High	Beta	SE	Low	High
Vodafone								
All-Share	0.87	0.08	0.77	0.07	0.93	0.06	0.84	0.04
All-World	0.82	0.12	0.52	0.08	0.90	0.09	0.66	0.06
All-EU	0.88	0.09	0.56	0.06	0.94	0.06	0.71	0.04
Telefonica								
All-Share	0.71	0.06	0.47	0.04	0.73	0.04	0.67	0.03
All-World	0.80	0.08	0.48	0.05	0.84	0.06	0.64	0.04
All-EU	0.86	0.06	0.53	0.04	0.87	0.04	0.72	0.03
France Telecom								
All-Share	0.53	0.07	0.35	0.05	0.58	0.05	0.51	0.03
All-World	0.58	0.10	0.40	0.06	0.65	0.07	0.55	0.05
All-EU	0.64	0.07	0.41	0.05	0.68	0.05	0.57	0.03
Deutsche Telekom								
All-Share	0.45	0.07	0.46	0.05	0.49	0.05	0.62	0.04
All-World	0.58	0.09	0.54	0.07	0.62	0.07	0.69	0.05
All-EU	0.54	0.07	0.48	0.05	0.57	0.05	0.64	0.04
Simple Average Across Companies								
All-Share	0.64		0.51		0.68		0.66	
All-World	0.69		0.48		0.75		0.64	
All-EU	0.73		0.50		0.77		0.66	

Table 2 shows the importance of timeframe. For Vodafone, Telefonica and France Telecom, pre-Lehman beta estimates come in a little above estimates reflecting the most up-to-date data, indicating a recent decline in betas. The same effect does not appear for Deutsche Telekom, where the pre-Lehman beta estimates are statistically indistinguishable from those reflecting the most up-to-date data. Figure 1 to Figure 4 plot "rolling" two-year beta estimates. All of the plots keep the duration of the beta estimation window constant through time. They simply shift the two-year data window forward as time passes.
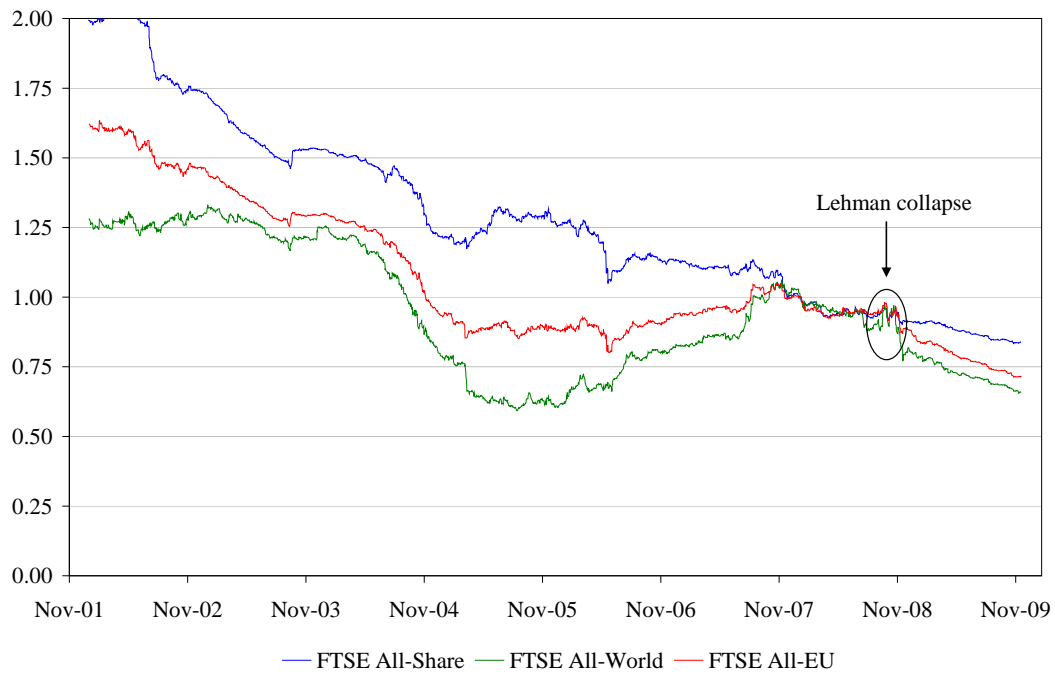
Figure 1: Vodafone two-year rolling beta

Lehman collapse

FTSE All-Share — FTSE All-World — FTSE All-EU

Figure 2: Telefonica two-year rolling beta

Lehman collapse

FTSE All-Share — FTSE All-World — FTSE All-EU
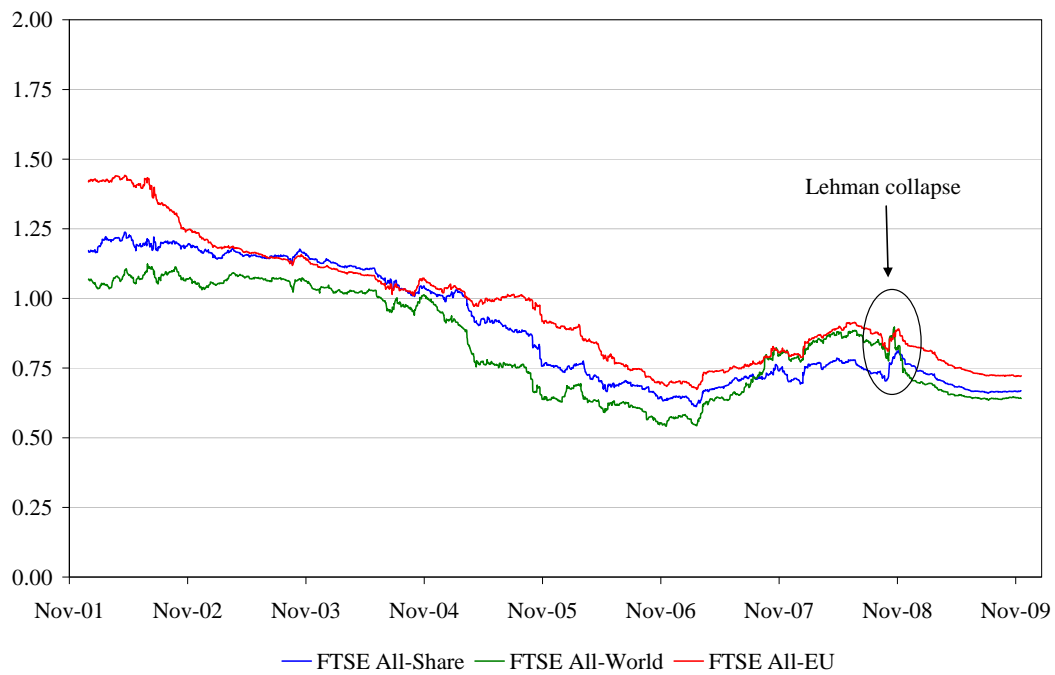
Figure 3: France Telecom two-year rolling beta

Lehman collapse

— FTSE All-Share — FTSE All-World — FTSE All-EU
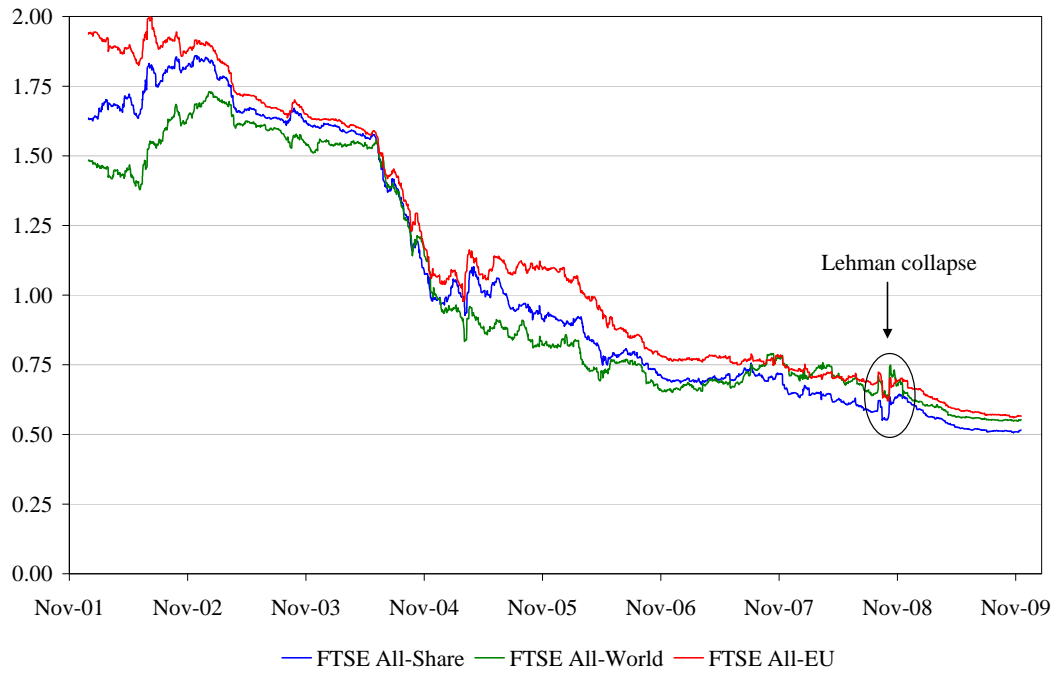
Figure 4: Deutsche Telekom two-year rolling beta

Lehman collapse

— FTSE All-Share — FTSE All-World — FTSE All-EU
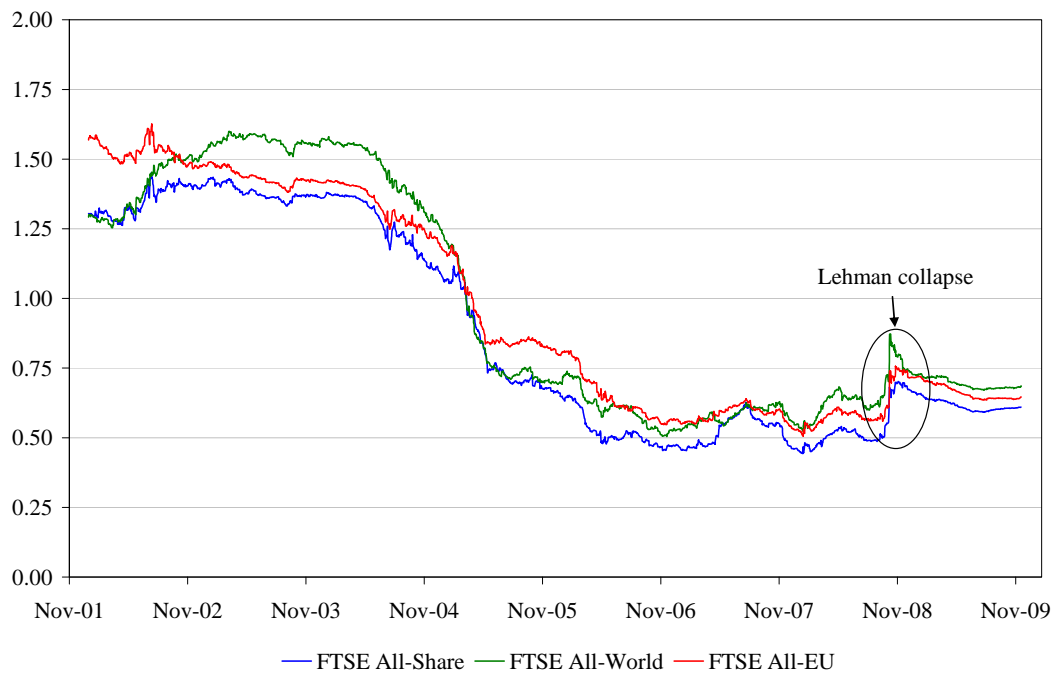
The most striking thing is the obvious similarity between the four plots. All four telecoms companies have seen a substantial reduction in their observed equity betas since 2002-2004. As we document in a subsequent section, changes in financial leverage cannot be the explanation.

One possible explanation is changing investor perceptions about the risk attached to telecoms stocks. In other words, investors now consider all four of these companies more like traditional utilities than in the past. Perhaps the reduction in risk stems in part from the bursting of the tech bubble. In its aftermath, investors may have been concerned that mobile stocks would promise much and deliver little. Several years of solid performance have finally persuaded investors otherwise and proved the resilience of telecoms majors.

An alternative and potentially complementary explanation might focus on the increasing maturity of mobile and other telecoms networks. Back in 2000, perhaps investors perceived the need for extensive investment to expand young and geographically limited networks. Extensive capex almost resembles fixed financial obligations like debt, because the investors could not expect to earn money without them. However, once major network expansion was completed and investments sunk, the companies could settle down to enjoy relatively stable and positive free cash flows. A reduction in "operational gearing" as networks matured may have prompted a reduction in the risk perceived by investors. This effect is present in other capital intensive industries such as toll roads, and the effect of operating leverage on risk is well documented in the literature. Further work would be required to identify whether operating leverage reductions could explain part of the apparent reduction in risk for all four telecoms companies.

Another striking thing about the four rolling beta plots is the volatility of the two-year beta estimates around September and October 2008, during the heart of the credit crisis. The extreme volatility of stock market movements around the world at that time seems to shift the two-year betas slightly (i.e. the lines wobble). Yet the events of September and October 2008 as a whole do not seem to alter the general trend of the rolling betas or cause a significant step-change in the level of the beta estimates. Only for Deutsche Telekom could we say that a step change occurred in September 2008, and this of the order of 0.20. Nevertheless, soon afterwards, the observed beta for Deutsche Telekom gives up most of the step gain from September, and it now sits at a level very similar to where it was in August 2008. In section three, we identify which particular data points exert the greatest influence on the beta estimates and investigate the impact of these points on the beta estimates. We find that the standard OLS betas are broadly stable to the exclusion of influential data points.

As highlighted earlier, we observe a slight downward trend in the two-year beta estimates since the heart of the credit crisis. Underlying the recent downward trend in the two-year betas may be a further step change in investors' risk perception of telecoms networks since the collapse of Lehman, as part of a fundamental re-evaluation of risk and a "flight to safety". A step change in risk perceptions will flow through slowly to the two-year beta estimate as more recent post-Lehman data replaces pre-crisis data. Potentially consistent with this view is the shape of the one-year beta estimates, which indicate a recent downward step change in the level of the betas. This step change occurs as data from before the Lehman collapse falls out of the rolling one-year data window and are replaced by more recent returns. Figure 5 plots rolling one-year beta estimates against the FTSE All-World for all four companies.

Figure 5: Rolling one-year betas against FTSE All-World
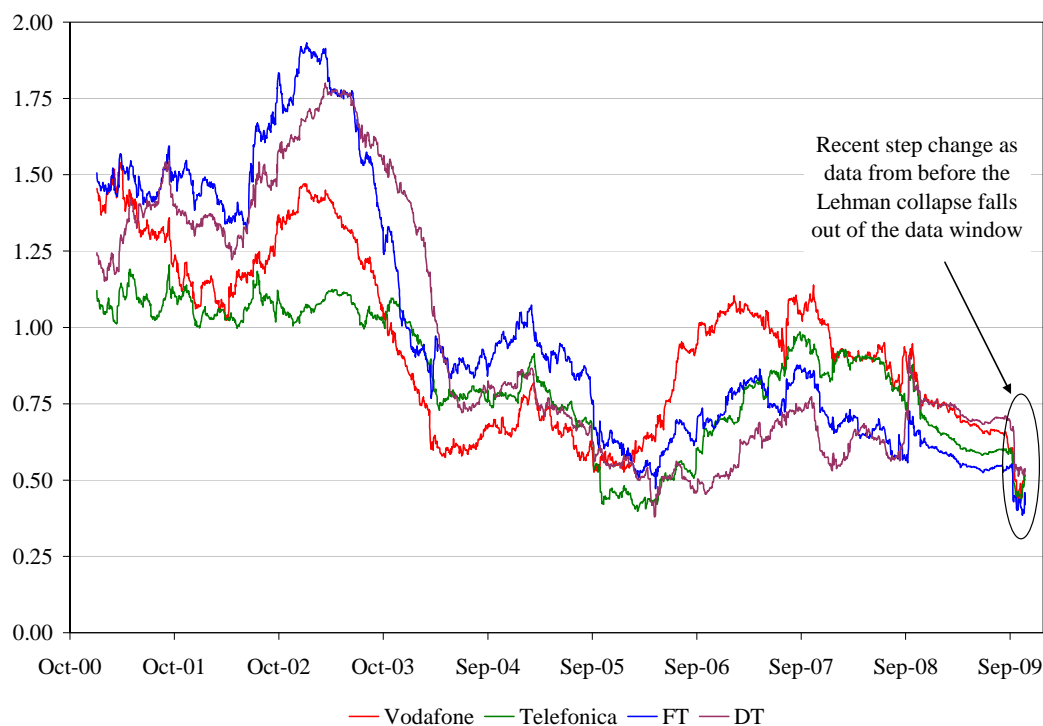
However, before we conclude that risk has reduced, we must note that the magnitude of the step change observed in the one-year betas remains within or close to twice the standard error. We cannot yet conclude that the more recent estimates are statistically different from those previous.

Also, an alternative explanation remains consistent with the observed patterns over time. Perhaps telecom/utilities perform differently in normal economic conditions than in crises. For example, investors might expect utility performance to be consistent with a beta of 0.75 during normal times, but then during crises, to outperform the market consistent with a beta of only 0.5. Performing at 0.75 during normal times and 0.5 during crises would result in overall utility returns greater than implied by a consistent 0.5 beta level throughout the crisis. In effect, investors might expect utilities to go up with the market during normal times at 0.75, but then in crises to go down with the market to less extent, consistent with only a 0.5 beta. As a result, investors might expect higher overall returns from utilities than predicted by the pure "crisis" beta of 0.5. Further investigation of the effects of the credit crisis is warranted but remains outside the scope of this report.

2.3 Financial leverage

Equity risk reflects the combination of underlying business risk (to do with the variability of revenues and the extent of fixed costs) and financial risk (to do with the presence of fixed debt obligations). Other things equal, the more debt a company has outstanding, the greater the equity risk and the higher the equity beta. In general, we would not consider trustworthy betas for companies experiencing extreme changes in financial leverage throughout the data window.

We obtained data on the amount of debt outstanding for each of the four telecoms companies between 2004 and the present. We obtained the majority of the data from

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Bloomberg, but filled in some gaps using data from the companies own annual reports. 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 assume that the market value of the debt of these four companies remains close to its face value throughout the period in question. This assumption is reasonable since all four companies enjoy high investment grade credit ratings. However, our approach may overstate leverage more recently, as corporate yields spiked during the credit crisis.

Figure 6 plots financial leverage for all four companies over time and indicates that none of the companies have experienced significant changes since 2004. Since the leverage changes over time are relatively small, they cannot possibly explain the large changes in the firms' equity betas through time. For example, Vodafone increased leverage from 20% to 35% since 2004. Increasing leverage by 15% implies a 25% rise in the equity beta. But over the same period, Vodafone has seen roughly 33% come off its equity beta. The explanation for the observed reduction in betas over time lies elsewhere.

Figure 6: Financial leverage
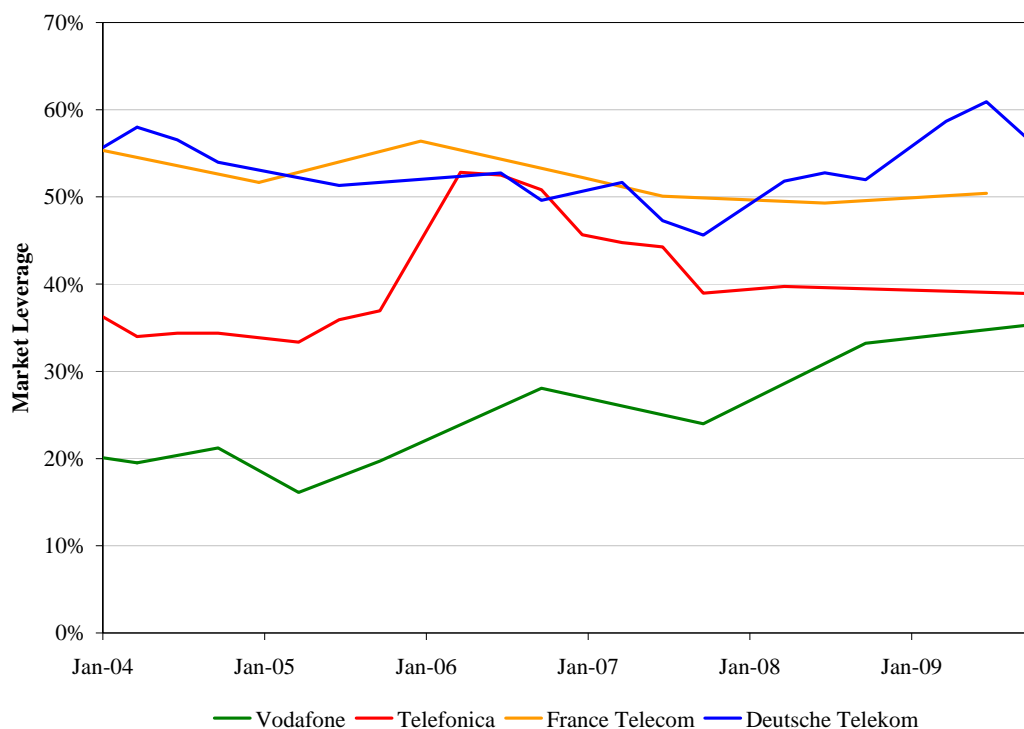
Two further figures explore the effect of financial leverage across companies. We focus on betas calculated against the FTSE All-World index. Figure 7 plots the equity betas for the four companies without making any adjustment for leverage. Figure 8 then plots the equivalent un-levered betas. That is, we take the equity betas from Figure 7 and then back out the impact of financial leverage using the simplest possible re-levering formula.[5] For input to the re-levering formula, we estimate average leverage across the rolling two-year data window.

Figure 7: Two-year equity betas against FTSE All-World

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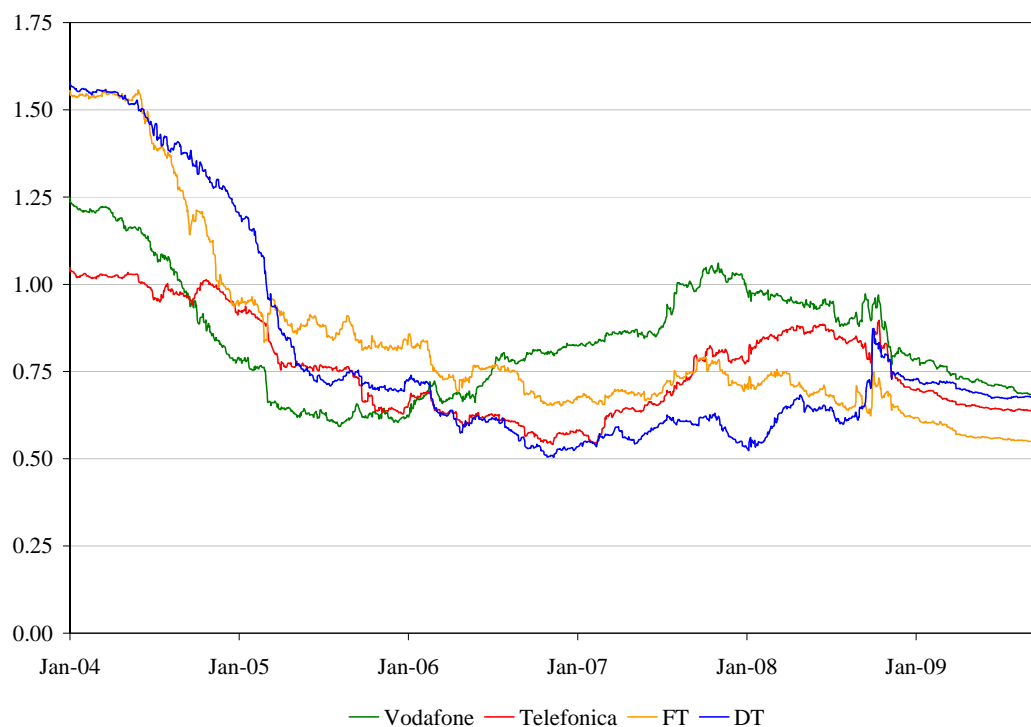
[5] We use a standard relevering formula (see *Principles of Corporate Finance* (8th edition), Brealey Myers and Allen, p. 518).

Figure 8: Two-year unlevered betas against FTSE All-World
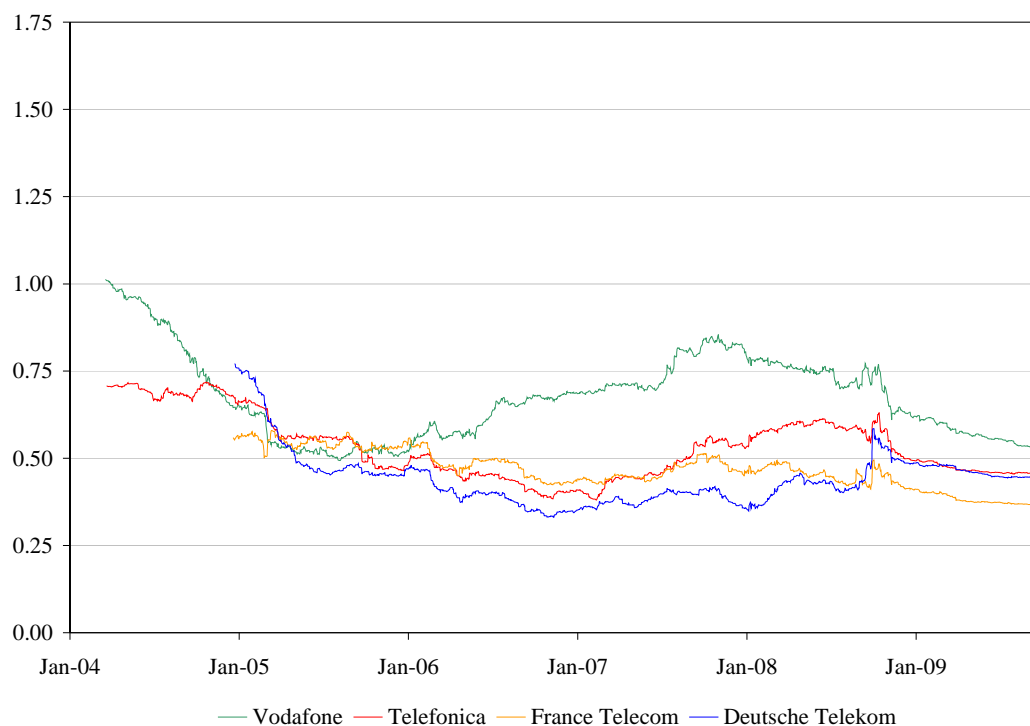
2.4 Discussion

The decrease in beta estimates over time for the four companies is not due to leverage changes. In chapter 3 we perform several statistical tests and confirm that the beta estimates are statistically reliable. Nevertheless, chapter 3 does not rule out the possibility that our estimates may simply be mid-points within relatively wide ranges, with the reported standard errors understating the true uncertainty of the estimates. Indeed, changing betas over time would introduce yet more uncertainty than suggested by standard OLS calculations.

The best current estimate for the equity betas of the companies are: 0.66 for Vodafone, 0.64 for Telefonica, 0.55 for France Telecom and 0.69 for Deutsche Telekom. We report betas against the FTSE All-World for three reasons:

- none of the companies represents a significant % of the All-World index by market capitalisation,

- all four companies pull substantial investment from all corners of the globe, and

- all four companies have significant operations spread across the globe.

We would normally recommend a range of +/- approximately two standard deviations around these mid-point figures—ie, a range of 0.46-0.79 in this case. However, we recommend further analysis before discounting the possibility that the companies' equity betas might lie outside this range.

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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.[6] We perform a number of statistical tests to check for potential problems in this case.

3.1 Dimson adjustment

To test for possible bias relating to trading illiquidity and to assess if time differences[7] caused distortions, we perform the "Dimson" adjustment to the estimated betas by including a one period lag and a one period lead. Over the four companies and two data periods, the separate coefficients of the lag and lead terms were seldom significantly different from zero and the Dimson adjustment overall was significantly different from zero for only five out of a total of 48 different beta estimates.

There is no discernable pattern as to when the Dimson adjustments appear significant. Three of the five occurrences relate to the FTSE All-Share: one concerning Vodafone where the lag term is significant and two concerning Telefonica where the lead term is significant. The other two occurrences relate to the FTSE All-World: one concerning Telefonica where the lead term is significant and once concerning Deutsche Telekom again where the lead term is significant. Only for Telefonica against the FTSE All-Share do the Dimson adjustments appear significant for the one and two year betas at the same time. Never does the Dimson adjustment appear significant for both the pre-Lehman and post-Lehman betas at the same time. For example, the adjustment appears significant for the Vodafone two-year beta against the FTSE All-Share using up-to-date data but not for the Vodafone two-year beta against the same index but using data prior to the collapse of Lehman. The five cases where the Dimson adjustment appears significant do not therefore appear to reflect any systematic effect. Table 3 and Table 4 report Dimson betas for each of the companies.

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

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

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

	1 Yr				2 Yr			
	Beta	Dimson Beta	SE of Dimson Beta	Significance	Beta	Dimson Beta	SE of Dimson Beta	Significance
Vodafone								
All-Share	0.77	0.63	0.14	No	0.84	0.59	0.11	Yes
All-World	0.52	0.42	0.19	No	0.66	0.59	0.14	No
All-EU	0.56	0.52	0.14	No	0.71	0.51	0.11	No
Telefonica								
All-Share	0.47	0.27	0.08	Yes	0.67	0.43	0.06	Yes
All-World	0.48	0.48	0.12	No	0.64	0.72	0.10	No
All-EU	0.53	0.42	0.08	No	0.72	0.55	0.06	Yes
France Telecom								
All-Share	0.35	0.25	0.10	No	0.51	0.36	0.08	No
All-World	0.40	0.33	0.14	No	0.55	0.39	0.10	No
All-EU	0.41	0.34	0.11	No	0.57	0.43	0.08	No
Deutsche Telekom								
All-Share	0.46	0.36	0.12	No	0.62	0.49	0.10	No
All-World	0.54	0.41	0.17	No	0.69	0.59	0.11	No
All-EU	0.48	0.45	0.13	No	0.64	0.60	0.10	No
Simple Average Across Companies								
All-Share	0.51	0.38			0.66	0.47		
All-World	0.48	0.41			0.64	0.57		
All-EU	0.50	0.43			0.66	0.52		

Table 4: Dimson adjustments – pre-Lehman data

	1 Yr				2 Yr			
	Beta	Dimson Beta	SE of Dimson Beta	Significance	Beta	Dimson Beta	SE of Dimson Beta	Significance
Vodafone								
All-Share	0.87	0.58	0.24	No	0.93	0.70	0.16	No
All-World	0.82	0.77	0.29	No	0.90	0.86	0.20	No
All-EU	0.88	0.81	0.22	No	0.94	0.88	0.15	No
Telefonica								
All-Share	0.71	0.53	0.14	No	0.73	0.64	0.09	No
All-World	0.80	0.55	0.21	No	0.84	0.75	0.14	No
All-EU	0.86	0.82	0.13	No	0.87	0.86	0.09	No
France Telecom								
All-Share	0.53	0.36	0.17	No	0.58	0.41	0.11	No
All-World	0.58	0.25	0.24	No	0.65	0.42	0.16	No
All-EU	0.64	0.54	0.14	No	0.68	0.66	0.10	No
Deutsche Telekom								
All-Share	0.45	0.53	0.20	No	0.49	0.63	0.13	No
All-World	0.58	0.30	0.19	No	0.62	0.48	0.13	No
All-EU	0.54	0.90	0.18	No	0.57	0.96	0.13	Yes
Simple Average Across Companies								
All-Share	0.51	0.38			0.66	0.47		
All-World	0.48	0.41			0.64	0.57		
All-EU	0.50	0.43			0.66	0.52		

3.2 Tests for heteroscedasticity and auto-correlation

We perform a series of standard diagnostic tests to assess if the beta estimates satisfy the standard conditions underlying ordinary least squares regression. The standard

conditions are that the error terms in the regression follow a normal distribution and that they do not suffer from heteroscedasticity (linked to the fitted values) or auto-correlation (follow some pattern over time). Failure to meet these conditions would not invalidate the beta estimates, but would have the following consequences:

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

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

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

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

Heteroscedasticity

Figure 9 to Figure 12 show scatter plots of the residuals against the returns predicted by the regression, for two-year regressions against the FTSE All-World. We constructed comparable plots for our regressions against the other indices and for our shorter one year beta estimates. Visual inspection does not reveal any obvious pattern - the "vertical spread" does not appear to change in any systematic way as we move horizontally across the graph. However, there are clearly a number of outliers.

Figure 9: Vodafone - residuals against fitted values
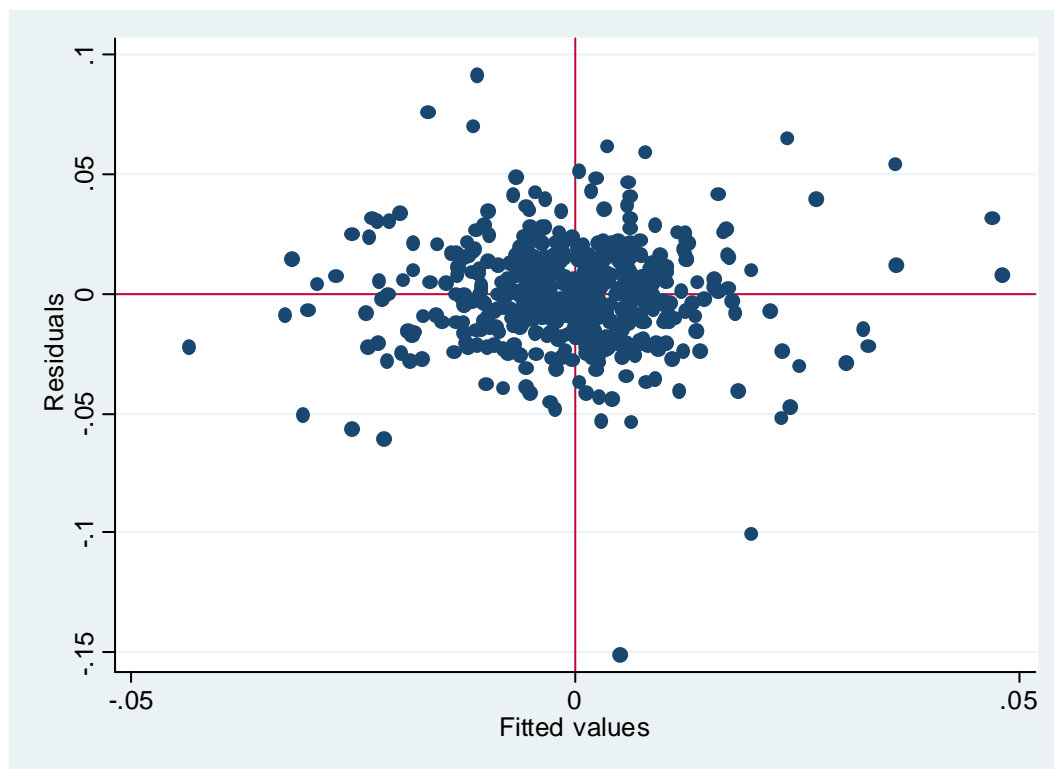
Figure 10: Telefonica - residuals against fitted values
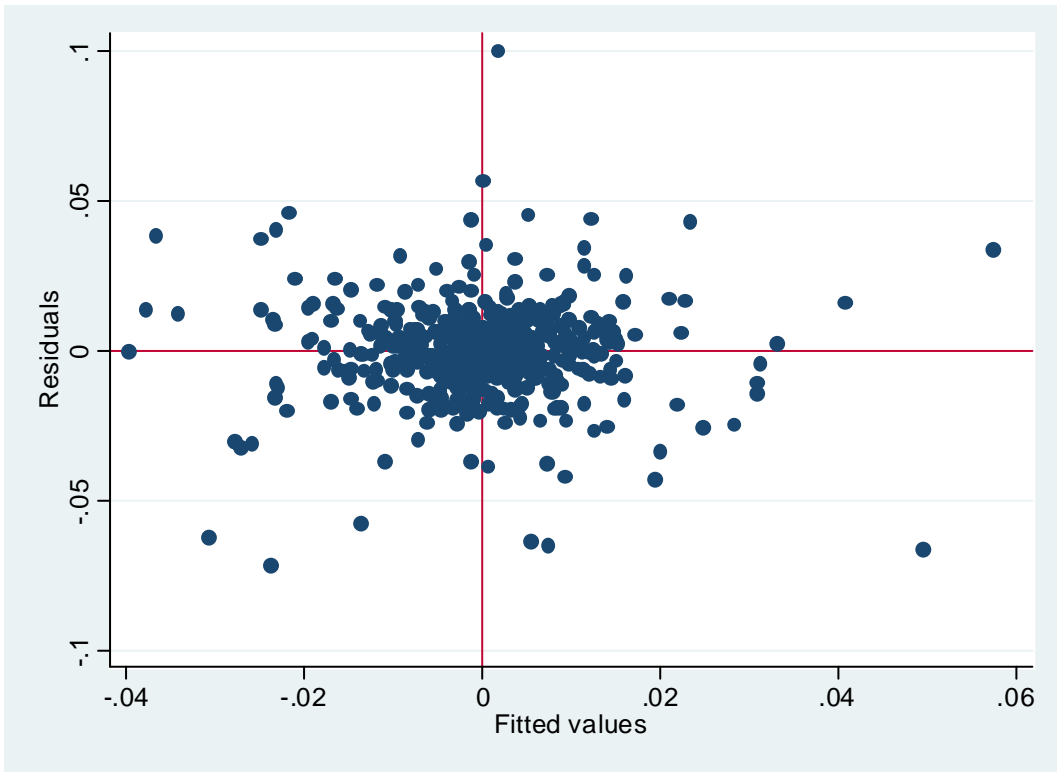
Figure 11: France Telecom – residuals against fitted values

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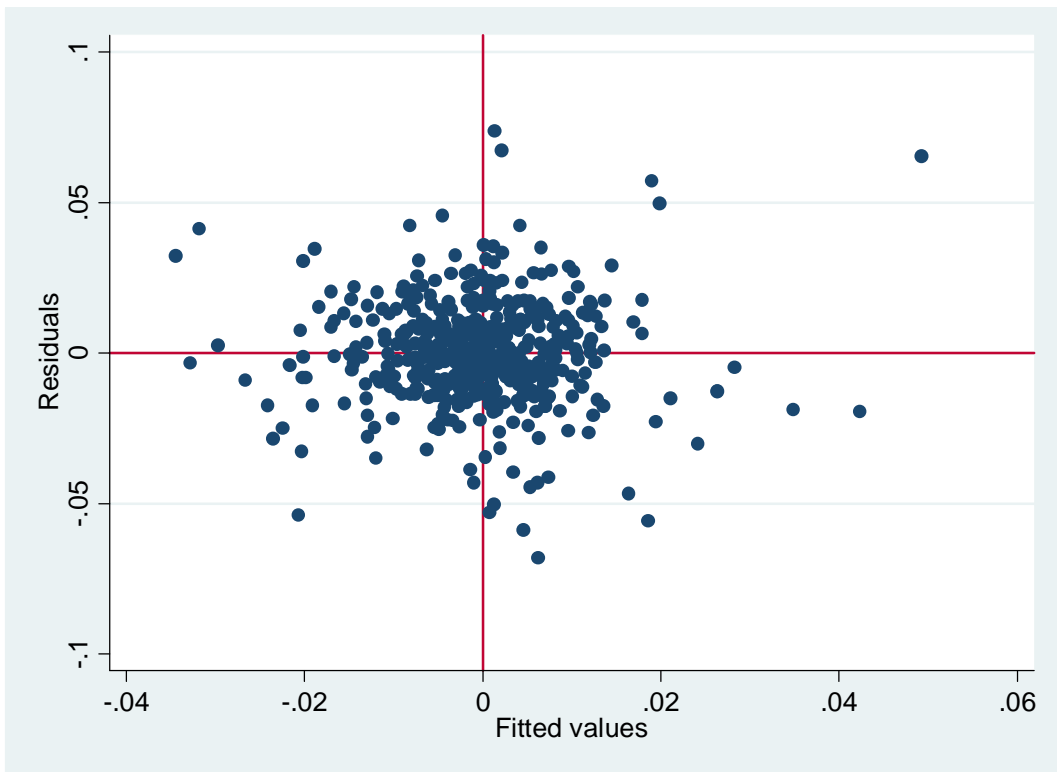
Figure 12: Deutsche Telekom – residuals against fitted values
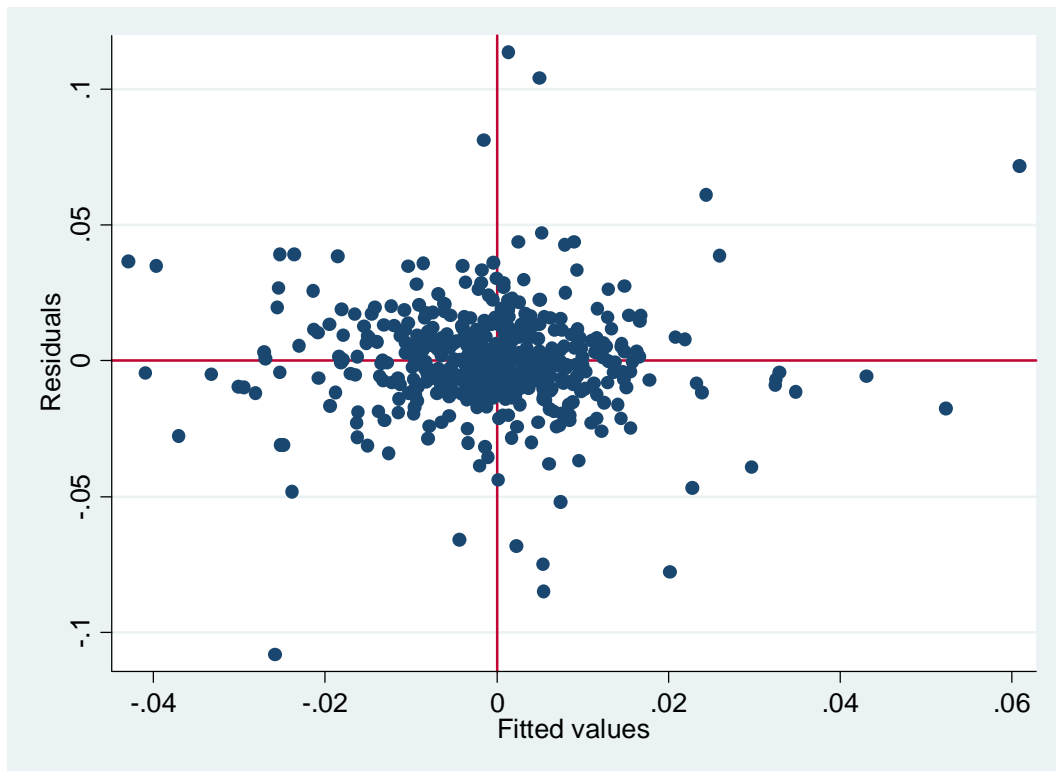
We also examine whether there is change in the pattern of residuals over time. Figure 13 to Figure 16 show an apparent peak in the magnitude of the residuals around the end of 2008, with the magnitude of residuals declining since then. All this appears to reflect market turmoil, and the extreme volatility witnessed during the heart of the credit crisis, as well as some recovery since then. The plots again relate to two-year beta estimates calculated against the FTSE All-World.

Figure 13: Vodafone - residuals over time
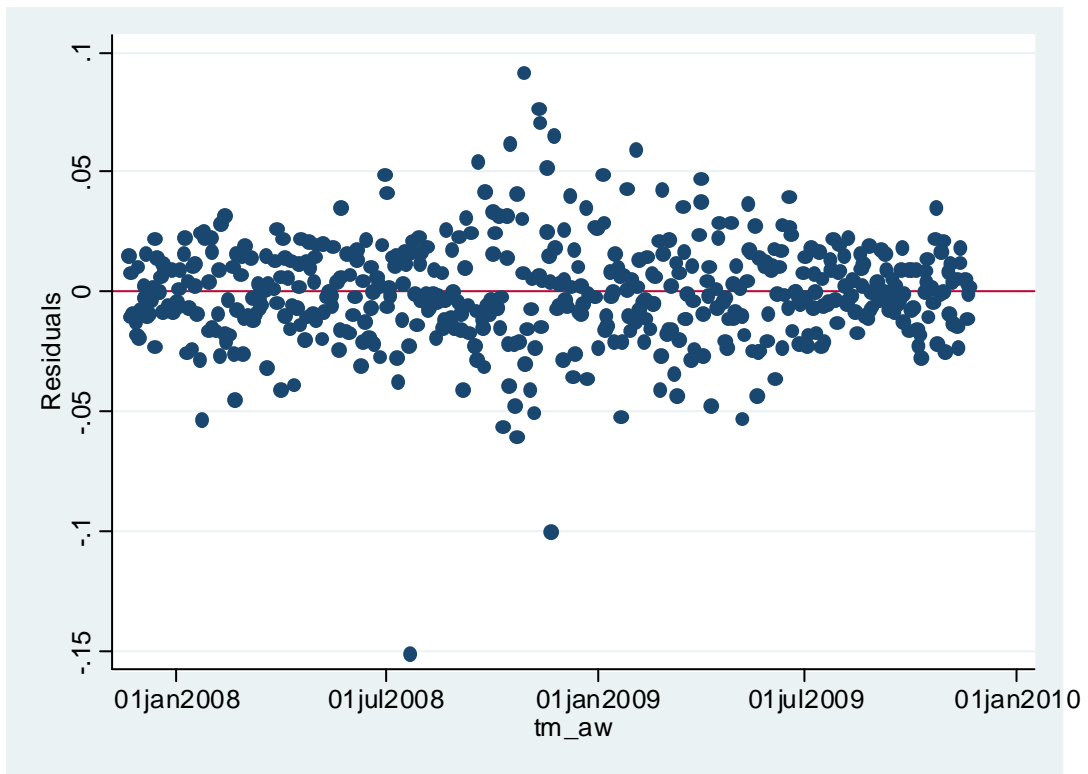
Figure 14: Telefonica – residuals over time

Figure 15: France Telecom – residuals over time
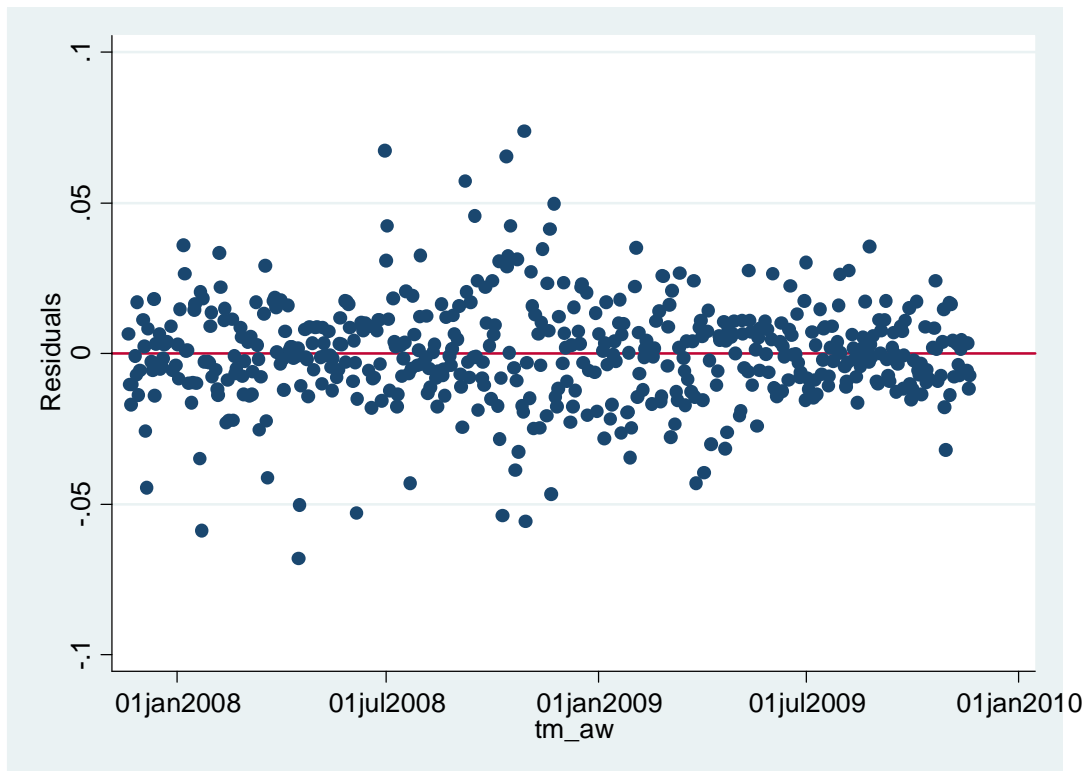
Figure 16: Deutsche Telekom – residuals over time
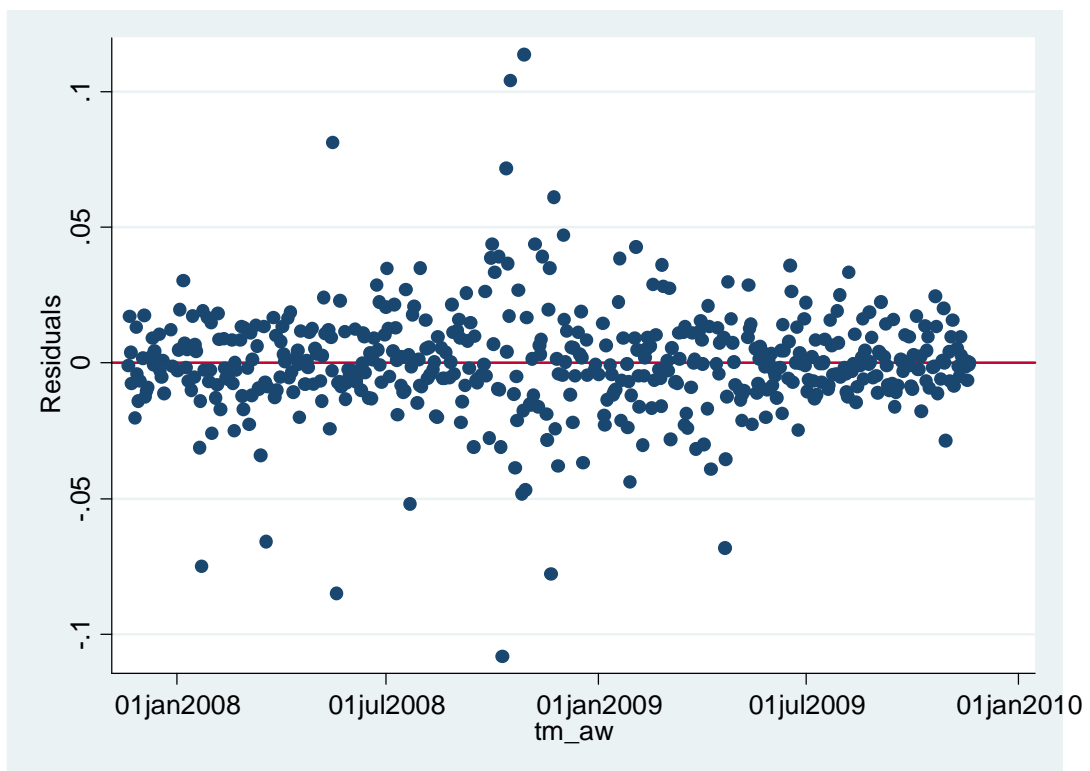
Since simple inspection suggests that there may be some heteroscedasticity, we apply a formal test (Cameron & Trivedi's decomposition) to investigate further. This test is similar to the White test, which we used in previous reports, but covers both

heteroskedascity and the skew and kurtosis of the errors. Table 5 and Table 6 report results.

Table 5: Cameron & Trivedi's test for heteroscedasticity – up-to-date data

|	1 Yr			2 Yr		
	Test Statistic	p-value	Significance	Test Statistic	p-value	Significance
Vodafone						
All-Share	0.43	0.81	No	1.39	0.50	No
All-World	23.91	-	Yes	5.07	0.08	No
All-EU	4.60	0.10	No	3.76	0.15	No
Telefonica						
All-Share	2.88	0.24	No	43.13	-	Yes
All-World	5.68	0.06	No	31.62	-	Yes
All-EU	3.08	0.21	No	39.17	-	Yes
France Telecom						
All-Share	17.04	0.00	Yes	35.53	-	Yes
All-World	9.33	0.01	Yes	37.26	-	Yes
All-EU	22.60	-	Yes	45.33	-	Yes
Deutsche Telekom						
All-Share	4.57	0.10	No	50.67	-	Yes
All-World	9.65	0.01	Yes	14.04	0.00	Yes
All-EU	8.46	0.01	No	48.30	-	Yes

Table 6: Cameron & Trivedi's test for heteroscedascity – pre-Lehman data

	1 Yr			2 Yr		
	Test Statistic	p-value	Significance	Test Statistic	p-value	Significance
Vodafone						
All-Share	0.98	0.61	No	0.94	0.63	No
All-World	1.23	0.54	No	0.96	0.62	No
All-EU	0.50	0.78	No	0.23	0.89	No
Telefonica						
All-Share	2.50	0.29	No	6.41	0.04	No
All-World	0.18	0.91	No	1.22	0.54	No
All-EU	0.45	0.80	No	1.83	0.40	No
France Telecom						
All-Share	0.71	0.70	No	2.97	0.23	No
All-World	1.70	0.43	No	0.47	0.79	No
All-EU	0.25	0.88	No	0.64	0.72	No
Deutsche Telekom						
All-Share	0.95	0.62	No	1.26	0.53	No
All-World	0.27	0.87	No	0.14	0.93	No
All-EU	0.21	0.90	No	0.15	0.93	No

The tables indicate the presence of some heteroscedascity in the up-to-date data, but none in the pre-Lehman data. This most likely relates to the significant increase in market volatility around the heart of the crisis.

Auto-correlation

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

Table 7: Durbin–Watson test for autocorrelation – up-to-date data

| | 1 Yr | | 2 Yr | |
	Test Statistic	Significance	Test Statistic	Significance
Vodafone				
All-Share	1.51	Yes	1.47	Yes
All-World	1.44	Yes	1.63	Yes
All-EU	1.44	Yes	1.48	Yes
Telefonica				
All-Share	1.39	Yes	1.42	Yes
All-World	1.60	Yes	1.92	No
All-EU	1.44	Yes	1.53	Yes
France Telecom				
All-Share	1.47	Yes	1.32	Yes
All-World	1.53	Yes	1.51	Yes
All-EU	1.44	Yes	1.30	Yes
Deutsche Telekom				
All-Share	1.59	Yes	1.41	Yes
All-World	1.61	Yes	1.51	Yes
All-EU	1.62	Yes	1.43	Yes

Table 8: Durbin–Watson test for autocorrelation – pre-Lehman collapse

	1 Yr		2 Yr	
	Test Statistic	Significance	Test Statistic	Significance
Vodafone				
All-Share	1.72	Yes	1.67	Yes
All-World	1.94	No	1.88	No
All-EU	1.79	No	1.73	Yes
Telefonica				
All-Share	1.40	Yes	1.41	Yes
All-World	1.36	Yes	1.40	Yes
All-EU	1.73	Yes	1.71	Yes
France Telecom				
All-Share	1.27	Yes	1.32	Yes
All-World	1.44	Yes	1.48	Yes
All-EU	1.28	Yes	1.33	Yes
Deutsche Telekom				
All-Share	1.40	Yes	1.33	Yes
All-World	1.44	Yes	1.36	Yes
All-EU	1.41	Yes	1.35	Yes

Robust regresssion

We do not think that the heteroscedasticity and auto-correlation are a significant problem. 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 9 and Table 10). The presence of auto-correlation should not affect the central beta estimates, but means that even the robust standard errors will underestimate the true level of uncertainty associated with the measurements.

Table 9: Robust standard errors – up-to-date data

	1 Yr			2 Yr		
	Beta	OLS SE	Robust SE	Beta	OLS SE	Robust SE
Vodafone						
All-Share	0.77	0.07	0.07	0.84	0.04	0.04
All-World	0.52	0.08	0.11	0.66	0.06	0.07
All-EU	0.56	0.06	0.07	0.71	0.04	0.05
Telefonica						
All-Share	0.47	0.04	0.04	0.67	0.03	0.04
All-World	0.48	0.05	0.07	0.64	0.04	0.07
All-EU	0.53	0.04	0.04	0.72	0.03	0.04
France Telecom						
All-Share	0.35	0.05	0.06	0.51	0.03	0.05
All-World	0.40	0.06	0.08	0.55	0.05	0.07
All-EU	0.41	0.05	0.06	0.57	0.03	0.05
Deutsche Telekom						
All-Share	0.46	0.05	0.06	0.62	0.04	0.07
All-World	0.54	0.07	0.09	0.69	0.05	0.08
All-EU	0.48	0.05	0.07	0.64	0.04	0.07
Simple Average Across Companies						
All-Share	0.51			0.66		
All-World	0.48			0.64		
All-EU	0.50			0.66		

Table 10: Robust standard errors – pre-Lehman collapse

	1 Yr			2 Yr		
	Beta	OLS SE	Robust SE	Beta	OLS SE	Robust SE
Vodafone						
All-Share	0.87	0.08	0.06	0.93	0.06	0.05
All-World	0.82	0.12	0.11	0.90	0.09	0.09
All-EU	0.88	0.09	0.07	0.94	0.06	0.06
Telefonica						
All-Share	0.71	0.06	0.06	0.73	0.04	0.04
All-World	0.80	0.08	0.09	0.84	0.06	0.07
All-EU	0.86	0.06	0.06	0.87	0.04	0.04
France Telecom						
All-Share	0.53	0.07	0.07	0.58	0.05	0.06
All-World	0.58	0.10	0.09	0.65	0.07	0.07
All-EU	0.64	0.07	0.07	0.68	0.05	0.06
Deutsche Telekom						
All-Share	0.45	0.07	0.07	0.49	0.05	0.06
All-World	0.58	0.09	0.09	0.62	0.07	0.07
All-EU	0.54	0.07	0.08	0.57	0.05	0.06
Simple Average Across Companies						
All-Share	0.64			0.68		
All-World	0.69			0.75		
All-EU	0.73			0.77		

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 17 to Figure 20 show histograms for two-year FTSE All-World regressions.

Figure 17: Studentized residuals - Vodafone
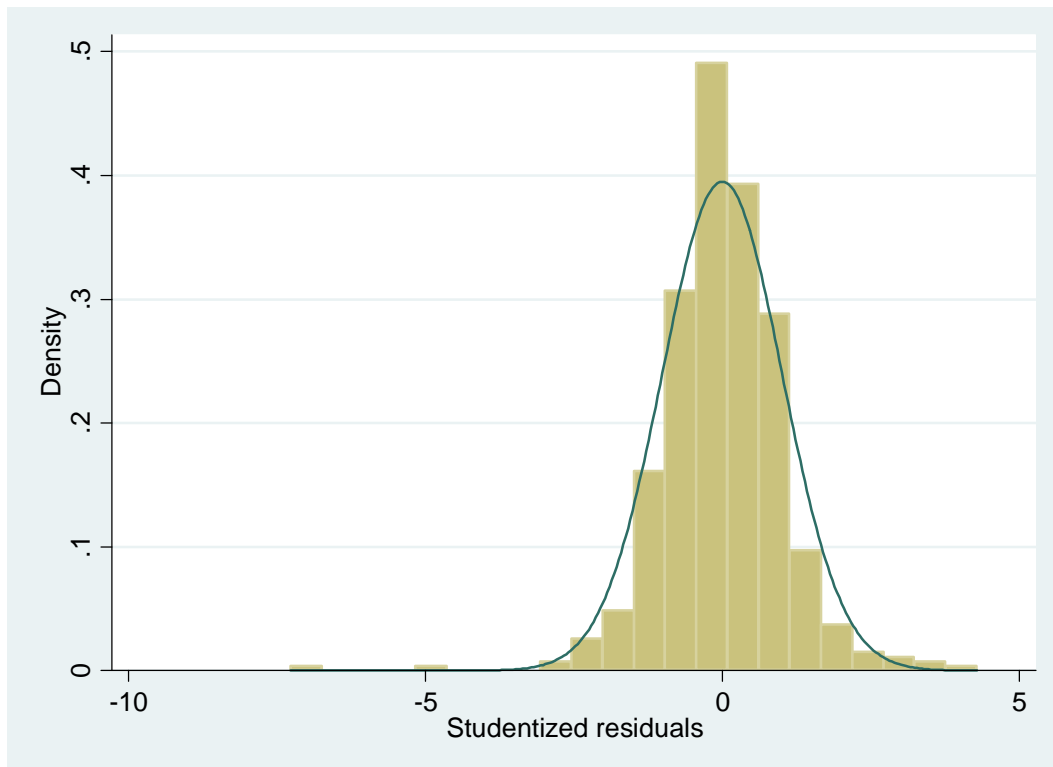
Figure 18: Studentized residuals – Telefonica
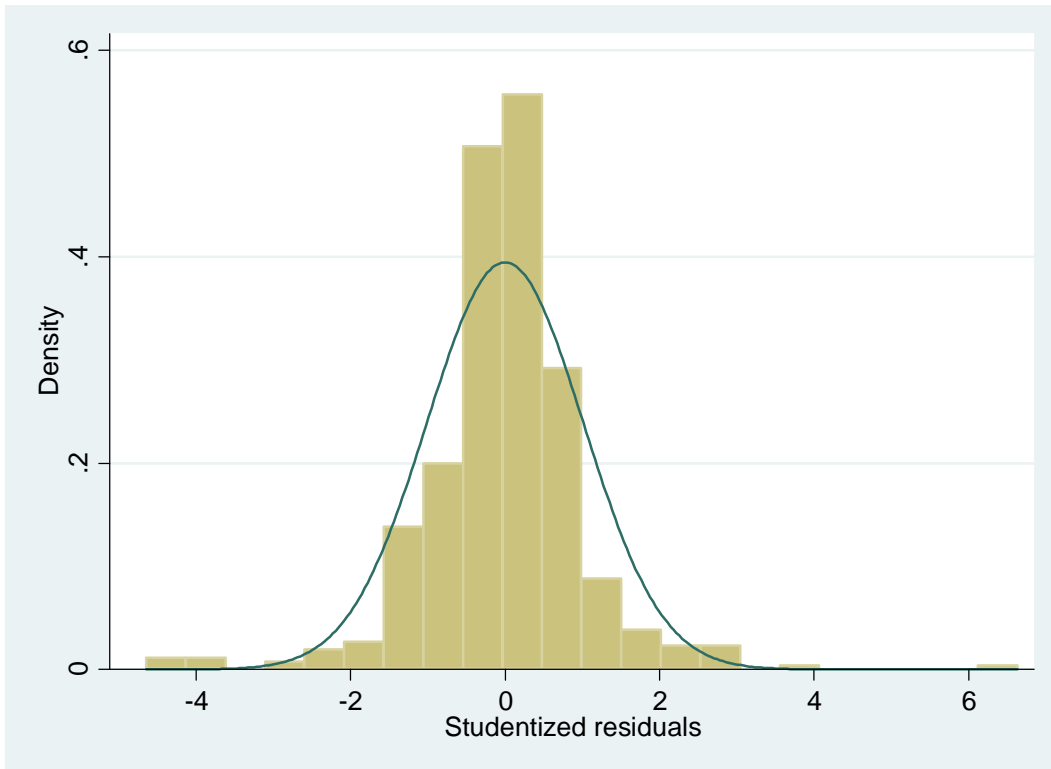
Figure 19: Studentized residuals – France Telecom

Figure 20: Studentized residuals – Deutsche Telekom

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 11 lists such influential dates for the two year betas calculated using up-to-date data. More than half of the influential "outliers" occurred during September to December 2008 – i.e. in the immediate aftermath of the collapse of Lehman Brothers. No other period of the data window contributes as many outliers.
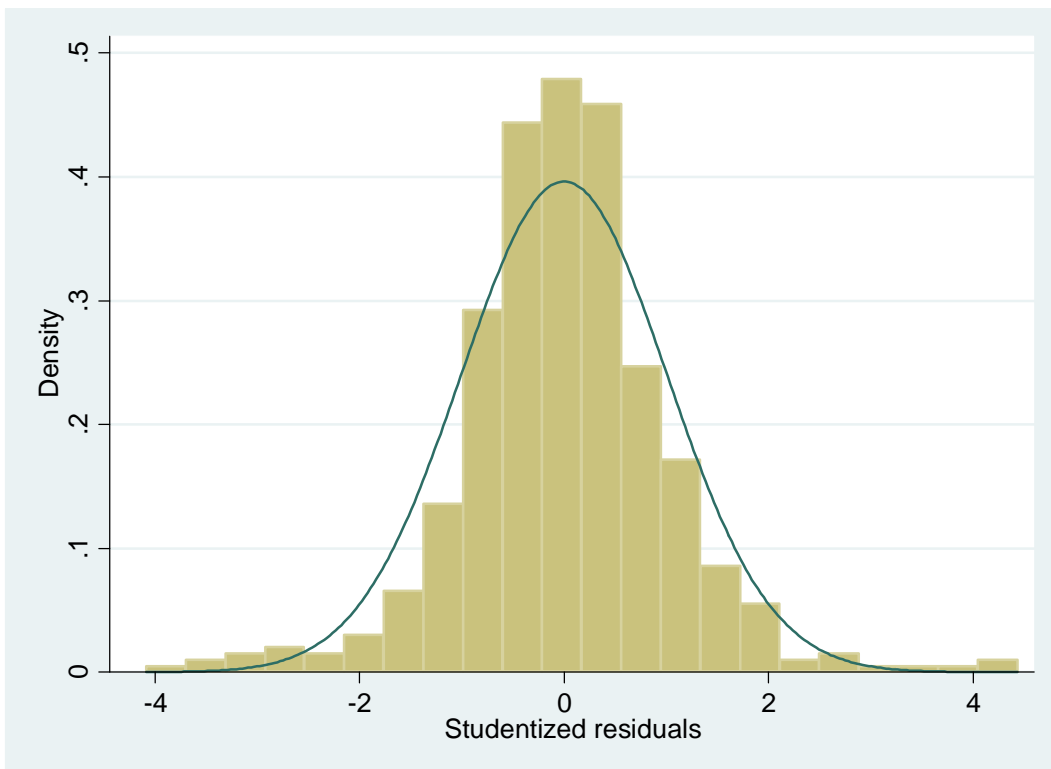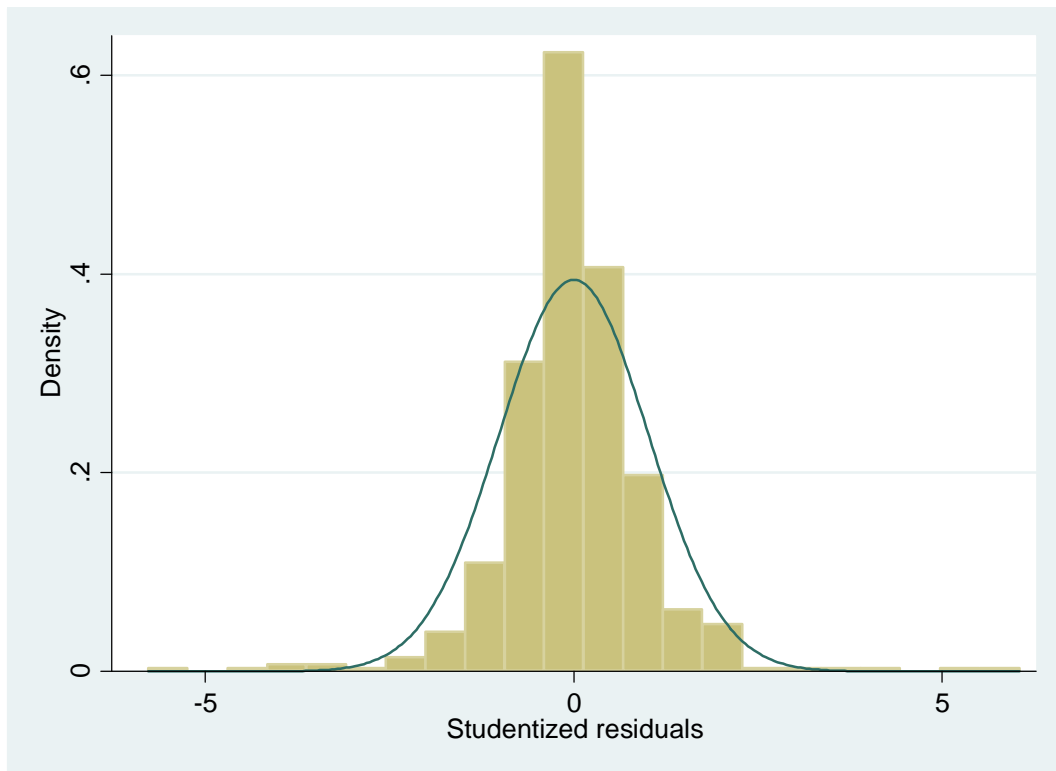
Table 11: Removing influential outliers, one-year regressions

Vodafone			Telefonica			France Telecom			Deutsche Telekom		
FTSE All-Share	FTSE All-World	FTSE All-EU	FTSE All-Share	FTSE All-World	FTSE All-EU	FTSE All-Share	FTSE All-World	FTSE All-EU	FTSE All-Share	FTSE All-World	FTSE All-EU
17-Mar-08	23-Jan-08	22-Jul-08	4-Dec-07	21-Jan-08	7-Jan-08	21-Jan-08	6-Dec-07	21-Jan-08	22-Jan-08	23-Jan-08	23-Jan-08
2-Jul-08	22-Jul-08	19-Sep-08	21-Jan-08	23-Jan-08	21-Jan-08	23-Jan-08	21-Jan-08	23-Jan-08	23-Jan-08	19-Mar-08	19-Mar-08
22-Jul-08	9-Sep-08	25-Sep-08	23-Jan-08	24-Jan-08	23-Jan-08	7-Feb-08	18-Mar-08	7-Feb-08	17-Mar-08	16-May-08	16-May-08
19-Sep-08	19-Sep-08	6-Oct-08	24-Jan-08	5-Feb-08	5-Feb-08	17-Mar-08	20-Mar-08	17-Mar-08	19-Mar-08	19-May-08	19-May-08
25-Sep-08	25-Sep-08	10-Oct-08	5-Feb-08	25-Mar-08	22-Jul-08	18-Mar-08	16-Apr-08	18-Mar-08	16-May-08	22-Jul-08	15-Sep-08
6-Oct-08	2-Oct-08	13-Oct-08	2-Jul-08	22-Jul-08	16-Sep-08	16-Apr-08	5-Jun-08	16-Apr-08	19-May-08	15-Sep-08	19-Sep-08
10-Oct-08	7-Oct-08	15-Oct-08	22-Jul-08	19-Sep-08	19-Sep-08	17-Apr-08	30-Jun-08	17-Apr-08	15-Sep-08	29-Sep-08	29-Sep-08
13-Oct-08	10-Oct-08	17-Oct-08	16-Sep-08	30-Sep-08	29-Sep-08	5-Jun-08	2-Jul-08	5-Jun-08	19-Sep-08	30-Sep-08	30-Sep-08
17-Oct-08	13-Oct-08	22-Oct-08	29-Sep-08	6-Oct-08	8-Oct-08	30-Jun-08	22-Jul-08	30-Jun-08	29-Sep-08	7-Oct-08	6-Oct-08
20-Oct-08	15-Oct-08	27-Oct-08	8-Oct-08	7-Oct-08	10-Oct-08	1-Jul-08	8-Sep-08	1-Jul-08	30-Sep-08	9-Oct-08	9-Oct-08
22-Oct-08	17-Oct-08	28-Oct-08	10-Oct-08	8-Oct-08	14-Oct-08	2-Jul-08	16-Sep-08	8-Sep-08	9-Oct-08	10-Oct-08	10-Oct-08
28-Oct-08	20-Oct-08	29-Oct-08	13-Oct-08	10-Oct-08	17-Oct-08	8-Sep-08	19-Sep-08	16-Sep-08	10-Oct-08	13-Oct-08	13-Oct-08
29-Oct-08	22-Oct-08	3-Nov-08	17-Oct-08	13-Oct-08	22-Oct-08	16-Sep-08	6-Oct-08	19-Sep-08	13-Oct-08	15-Oct-08	15-Oct-08
4-Nov-08	27-Oct-08	6-Nov-08	22-Oct-08	17-Oct-08	28-Oct-08	19-Sep-08	7-Oct-08	8-Oct-08	15-Oct-08	17-Oct-08	16-Oct-08
6-Nov-08	29-Oct-08	11-Nov-08	27-Oct-08	22-Oct-08	29-Oct-08	8-Oct-08	8-Oct-08	10-Oct-08	16-Oct-08	24-Oct-08	17-Oct-08
11-Nov-08	30-Oct-08	12-Nov-08	28-Oct-08	27-Oct-08	4-Nov-08	10-Oct-08	10-Oct-08	13-Oct-08	17-Oct-08	27-Oct-08	24-Oct-08
12-Nov-08	3-Nov-08	17-Nov-08	29-Oct-08	28-Oct-08	6-Nov-08	13-Oct-08	15-Oct-08	15-Oct-08	24-Oct-08	28-Oct-08	27-Oct-08
21-Nov-08	6-Nov-08	21-Nov-08	4-Nov-08	29-Oct-08	11-Nov-08	15-Oct-08	24-Oct-08	16-Oct-08	27-Oct-08	29-Oct-08	29-Oct-08
24-Nov-08	11-Nov-08	24-Nov-08	6-Nov-08	4-Nov-08	12-Nov-08	16-Oct-08	28-Oct-08	17-Oct-08	29-Oct-08	30-Oct-08	7-Nov-08
8-Dec-08	12-Nov-08	8-Dec-08	12-Nov-08	6-Nov-08	20-Nov-08	17-Oct-08	29-Oct-08	24-Oct-08	7-Nov-08	7-Nov-08	11-Nov-08
3-Feb-09	17-Nov-08	2-Jan-09	20-Nov-08	12-Nov-08	1-Dec-08	24-Oct-08	30-Oct-08	29-Oct-08	13-Nov-08	14-Nov-08	20-Nov-08
30-Mar-09	21-Nov-08	5-Jan-09	1-Dec-08	13-Nov-08	26-Jan-09	29-Oct-08	6-Nov-08	30-Oct-08	20-Nov-08	20-Nov-08	21-Nov-08
2-Apr-09	24-Nov-08	3-Feb-09	5-Jan-09	14-Nov-08	29-Jan-09	30-Oct-08	14-Nov-08	6-Nov-08	21-Nov-08	21-Nov-08	24-Nov-08
24-Apr-09	8-Dec-08	30-Mar-09	6-Jan-09	20-Nov-08	20-Feb-09	6-Nov-08	20-Nov-08	20-Nov-08	24-Nov-08	24-Nov-08	27-Nov-08
19-May-09	21-Jan-09	31-Mar-09	27-Jan-09	21-Nov-08	26-Feb-09	13-Nov-08	21-Nov-08	24-Nov-08	27-Nov-08	20-Jan-09	2-Dec-08
17-Jun-09	3-Feb-09	2-Apr-09	26-Feb-09	24-Nov-08	2-Mar-09	20-Nov-08	24-Nov-08	8-Dec-08	5-Dec-08	9-Apr-09	5-Dec-08
	23-Mar-09	9-Apr-09	2-Mar-09	1-Dec-08	4-Mar-09	24-Nov-08	8-Dec-08	2-Feb-09	8-Dec-08	21-Apr-09	8-Dec-08
	9-Apr-09	22-Apr-09	4-Mar-09	5-Dec-08	10-Mar-09	8-Dec-08	9-Apr-09	3-Feb-09	6-Jan-09		20-Jan-09
		39940	30-Apr-09	11-Dec-08	2-Apr-09	18-Dec-08		20-Feb-09	3-Feb-09		26-Jan-09
		39952	12-May-09	17-Dec-08	9-Apr-09	31-Dec-08		10-Mar-09	21-Apr-09		3-Feb-09
		39981		27-Jan-09	30-Apr-09	6-Jan-09		2-Apr-09	5-May-09		20-Feb-09
				26-Feb-09	12-May-09	26-Jan-09		9-Apr-09	17-Jun-09		19-Mar-09
				9-Apr-09	21-May-09	30-Jan-09		17-Jun-09			9-Apr-09
						2-Feb-09					21-Apr-09
						4-Feb-09					22-Apr-09
						25-Mar-09					17-Jun-09
						2-Apr-09					24-Jun-09
						5-May-09					
% of Outliers During Sep-Dec 2008											
65%	61%	55%	57%	52%	50%	45%	55%	50%	53%	63%	46%

Table 12 and Table 13 compare the beta estimates obtained using standard OLS with those obtained through the iterative regression giving less weight to outliers and through a regression with all influential outliers removed. The broad similarity between the standard beta estimates and the other estimates provides confidence that outliers are not driving the results.

Table 12: Influential outliers – up-to-date data

	1 Yr			2 Yr		
	Standard Beta	Robust, iterative regression No Outliers	Number of outliers	Standard Beta	Robust, iterative regression No Outliers	Number of outliers
Vodafone						
All-Share	0.77	0.75	0.75	10	0.84	0.85	0.81	26
All-World	0.52	0.53	0.52	14	0.66	0.69	0.69	28
All-EU	0.56	0.54	0.49	17	0.71	0.73	0.67	31
Telefonica						
All-Share	0.47	0.45	0.45	15	0.67	0.59	0.61	30
All-World	0.48	0.51	0.54	17	0.64	0.66	0.65	33
All-EU	0.53	0.52	0.53	18	0.72	0.66	0.69	34
France Telecom						
All-Share	0.35	0.34	0.42	17	0.51	0.52	0.55	38
All-World	0.40	0.37	0.37	14	0.55	0.51	0.56	31
All-EU	0.41	0.39	0.45	17	0.57	0.56	0.58	34
Deutsche Telekom						
All-Share	0.46	0.42	0.44	16	0.62	0.46	0.51	32
All-World	0.54	0.06	0.54	16	0.69	0.60	0.65	27
All-EU	0.48	0.44	0.50	20	0.64	0.49	0.56	37
Simple Average Across Companies						
All-Share	0.51	0.49	0.51		0.66	0.60	0.62	
All-World	0.48	0.37	0.49		0.64	0.62	0.64	
All-EU	0.50	0.47	0.49		0.66	0.61	0.63	

Table 13: Influential outliers – pre-Lehman collapse

	1 Yr			2 Yr		
	Standard Beta	Robust, iterative regression No Outliers	Number of outliers	Standard Beta	Robust, iterative regression No Outliers	Number of outliers
Vodafone						
All-Share	0.87	0.84	0.82	10	0.93	0.91	0.88	27
All-World	0.82	0.86	0.81	10	0.90	0.89	0.82	27
All-EU	0.88	0.85	0.81	10	0.94	0.91	0.87	25
Telefonica						
All-Share	0.71	0.65	0.64	11	0.73	0.70	0.73	27
All-World	0.80	0.81	0.74	10	0.84	0.84	0.84	25
All-EU	0.86	0.83	0.84	13	0.87	0.86	0.86	23
France Telecom						
All-Share	0.53	0.60	0.58	13	0.58	0.67	0.63	24
All-World	0.58	0.71	0.69	16	0.65	0.79	0.74	25
All-EU	0.64	0.68	0.66	13	0.68	0.74	0.73	26
Deutsche Telekom						
All-Share	0.45	0.42	0.45	13	0.49	0.45	0.49	25
All-World	0.58	0.62	0.63	11	0.62	0.64	0.65	21
All-EU	0.54	0.52	0.56	12	0.57	0.54	0.57	25
Simple Average Across Companies						
All-Share	0.64	0.63	0.62		0.68	0.68	0.68	
All-World	0.69	0.75	0.72		0.75	0.79	0.76	
All-EU	0.73	0.72	0.72		0.77	0.76	0.76	