Estimates of Equity and Asset Betas for UK Mobile Owners

PREPARED FOR

Office of Communications ("Ofcom")

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June, 2014

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Acknowledgement: We acknowledge the valuable contributions of many individuals to this report and to the underlying analysis, including members of The Brattle Group for peer review.

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I. Introduction

Ofcom has asked us to update our estimates of the equity betas for the parent companies of the mobile network operators ("MNOs"): Vodafone, Telefonica (O2), Orange and Deutsche Telekom (EE).[1] We understand that Ofcom intends to use these estimates to inform its forthcoming decision on the level of UK mobile call termination charges. We perform various analyses and present equity and asset beta estimates for the four parent companies.

Interpretation of the updated results requires care. As we highlighted in previous reports, none of the above three UK MNOs has a dedicated tracking stock.[2] 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. 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.

To provide economic context and aid interpretation, we examine equity and asset betas for three further reference samples:

1. *UK Utilities* - The first reference sample comprises six other publicly traded UK utilities: National Grid (the gas and electricity transmission system operator), a further three water utilities (United Utilities, Severn Trent, and Pennon Group), and two other energy utilities, Centrica and SSE which combine regulated and unregulated activities. All of the companies in the UK utility peer group provide essential services and are subject to regulated price-caps, at least to some extent. A utility peer group subject to UK price regulation represents a useful peer group against which to compare the results of our equity and asset beta calculations for the UK MNOs and assess the relative riskiness of regulated activities.
2. *US Telecoms* - The second reference sample comprises a sample of liquidly traded US telecommunications stocks. Some of the companies in the US sample, such as AT&T and Verizon, resemble the four mobile network owners: large diversified telecommunications companies, engaging in a mixture of wireline and wireless

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[1] Ofcom did not ask us to consider Hutchison Whampoa, the owner of 3 since it is a diversified conglomerate operating across a number of sectors including retail, ports and telecoms. Beta estimates for Hutchison Whampoa are therefore unlikely to convey any useful information about a UK mobile operator.

[2] Neither has H3G. The stock of its parent, Hutchison Whampoa, is traded on the Hong Kong stock exchange.

activities. In contrast, others of the US sample, such as US Cellular, focus only on the provision of wireless services. The US telecommunications sample is interesting for two reasons: in part because it provides a reference sample of wireless only stocks, and in part because it enables comparison of the relative risks of wireless and wireline telecommunications services.

3. *EU Telecoms* - The third reference sample comprises a group of liquidly traded European telecommunications stocks, other than those owning UK mobile networks. Like the US sample, the European sample includes both large diversified telecoms companies and smaller companies focusing predominantly on wireless activities. We use the European sample also to examine the relative riskiness of mobile-only and diversified companies.

In this report, we adopt the same methodology as in other previous engagements for Ofcom.[3] We calculate daily returns from holding stock in each of the companies under consideration, and from holding a broad 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-Europe reflecting the European portion of the 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 the 31st of January 2014.

Previous work for Ofcom examined beta estimation methods.[4] One issue concerned the frequency with which to measure stock returns: whether to use daily, weekly or even monthly returns. Analysts might use weekly or monthly returns if there is a concern about the liquidity of stock trading. No such concern exists with the MNOs in this case. All four parent companies of the UK MNOs 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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[3] *See, for example,* Estimate of BT's Equity Beta (March 2014) and Estimate of Equity Beta for UK Mobile Owners (November 2010).

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

Chapter II presents equity and asset beta estimates for the UK MNOs, the UK utility, US Telecom and EU Telecom samples. Chapter III reports the results of several tests of the statistical reliability of the beta estimates.

II. Equity and Asset Beta Estimates

II.A. Parent Companies of UK MNOs

II.A.1. Up-to-date Equity Beta Estimates

Each of the four parent companies of the UK MNOs is involved in numerous activities. Vodafone's operations span Europe and Asia, and are predominantly mobile. Since 2007, wireless activities have accounted for around 90% of Vodafone's revenues. Over the same period, Vodafone's UK operations have accounted for approximately 7% of revenues.

Telefonica's operations span Europe and Latin America. Since 2007, mobile services have contributed an average of just over 64% of revenues. Telefonica's UK activities (almost entirely O2) have contributed just over 10% of group revenues.

Orange's principal operations are in France, Spain and Poland, in addition to EE in the UK. Since 2008, wireless activities have contributed just over 50% of revenues. EE has accounted for just over 15% of group revenues.

Deutsche Telekom's principal segments are in Germany, the US and the rest of Europe. Unfortunately, Deutsche Telekom does not breakout its segment reporting any further to reveal the precise extent of revenues obtained from mobile or wireline services. Nevertheless, we note that roughly two thirds of Deutsche Telekom's fixed network and broadband lines are located in Germany, while only a third of its mobile customers are located in Germany. Assuming that only a third of German revenues derive from mobile, that 100% of US revenues derive from mobile, and that two thirds of other European revenues derive from mobile, we estimate that just over 50% of Deutsche Telekom's revenues come from mobile.

Table 1 reports up-to-date equity beta estimates for the four parent companies of the UK MNOs. All of the estimates rely on daily return data. We report separate one and two year equity beta estimates as well as separate estimates against the three market indices. A one-year equity beta relies on the previous year of trading activity. A two-year equity beta relies on the previous two years. All of the various estimates reflect data up to and including the end of January 2014.

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

	1 Yr				2 Yr			
	Beta	SE	Low	High	Beta	SE	Low	High
Deutsche Telekom								
All World	0.87	0.10	0.67	1.07	0.81	0.08	0.66	0.96
All Share	0.85	0.09	0.68	1.02	0.78	0.06	0.66	0.90
All Europe	0.87	0.08	0.72	1.02	0.81	0.05	0.71	0.91
Orange								
All World	1.12	0.13	0.86	1.38	1.03	0.10	0.83	1.22
All Share	1.05	0.12	0.82	1.29	0.96	0.08	0.79	1.12
All Europe	1.15	0.10	0.96	1.34	1.10	0.07	0.97	1.24
Telefonica								
All World	1.09	0.12	0.86	1.32	1.05	0.11	0.83	1.27
All Share	1.01	0.09	0.83	1.19	1.01	0.09	0.84	1.18
All Europe	1.12	0.08	0.97	1.27	1.19	0.07	1.05	1.34
Vodafone								
All World	0.76	0.11	0.57	0.97	0.70	0.07	0.56	0.84
All Share	0.90	0.10	0.71	1.07	0.73	0.06	0.62	0.84
All Europe	0.58	0.08	0.43	0.73	0.47	0.05	0.37	0.56
MNO Average								
All World	0.96				0.90			
All Share	0.95				0.87			
All Europe	0.93				0.90			

Note:
We report OLS betas except where diagnostic tests indicate the presence of either heteroskedascity or auto-correlation. In which case we report GLS betas. We identified autocorrelation for the one and two year equity betas of Deutsche Telekom, Orange and Telefonica against all three indices.

Figure 1 illustrates the development of Vodafone's equity beta against the FTSE All-Share over time. Figure 2 plots Vodafone's one year equity beta against the FTSE All-Share, FTSE All-World and FTSE All-Europe. Figure 3 plots Vodafone's two-year equity beta against the same indices. In each case, the plot keeps the duration of the equity beta estimation window constant through time. It simply shifts the one or two-year data window forward as time passes. It illustrates the relative changes in both Vodafone's one-year and two-year equity betas over the past several years. Vodafone's one-year equity beta against the FTSE All-Share has fallen, risen, fallen again and risen again since the collapse of Lehman in September 2008. The recent rise – since the beginning of 2013, has seen Vodafone's one-year equity beta reach

[5] Low and high refer to the 95% confidence interval and not to the lowest and highest one and two-year betas observed throughout the year.

levels last seen in early 2011, and before the collapse of Lehman in 2008. In contrast, the two-year equity beta against the FTSE All-Share has remained relatively stable since the beginning of 2011 and has just trended slowly upward during the past six months. Figure 2 and Figure 3 show the same progression in the equity betas calculated against the other two indices, although the equity betas against the FTSE All-Share come in consistently above those against the other indices. This may reflect in part Vodafone's significant contribution to the FTSE All-Share itself.

Figure 1: Vodafone rolling equity betas against the FTSE All-Share – one-year and two-years

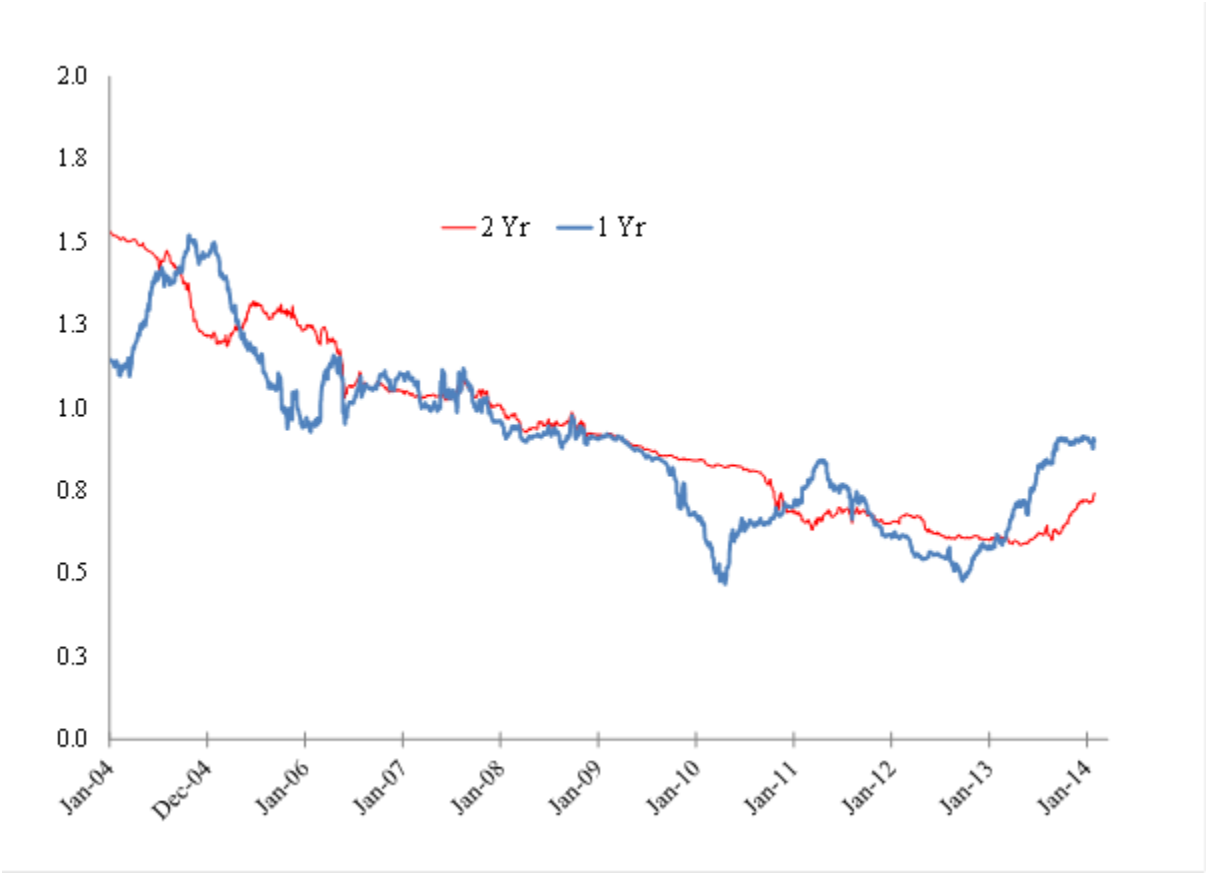


Figure 2: Vodafone rolling equity betas – one-year

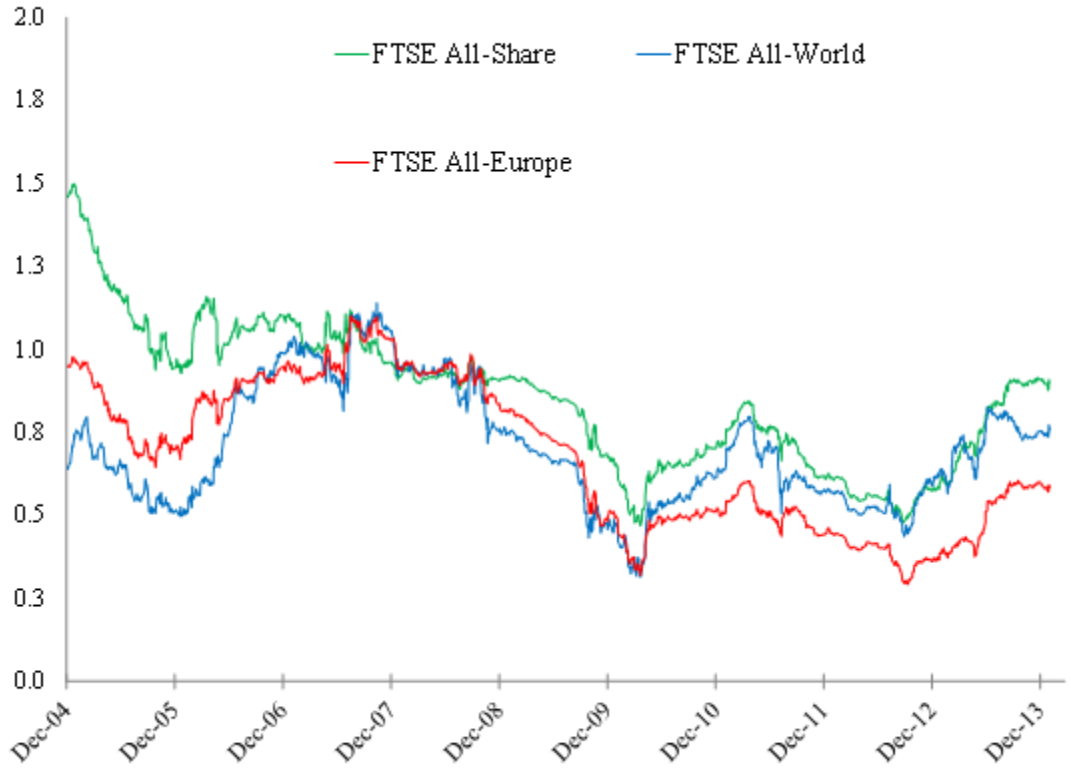


Figure 3: Vodafone rolling equity betas – two-year

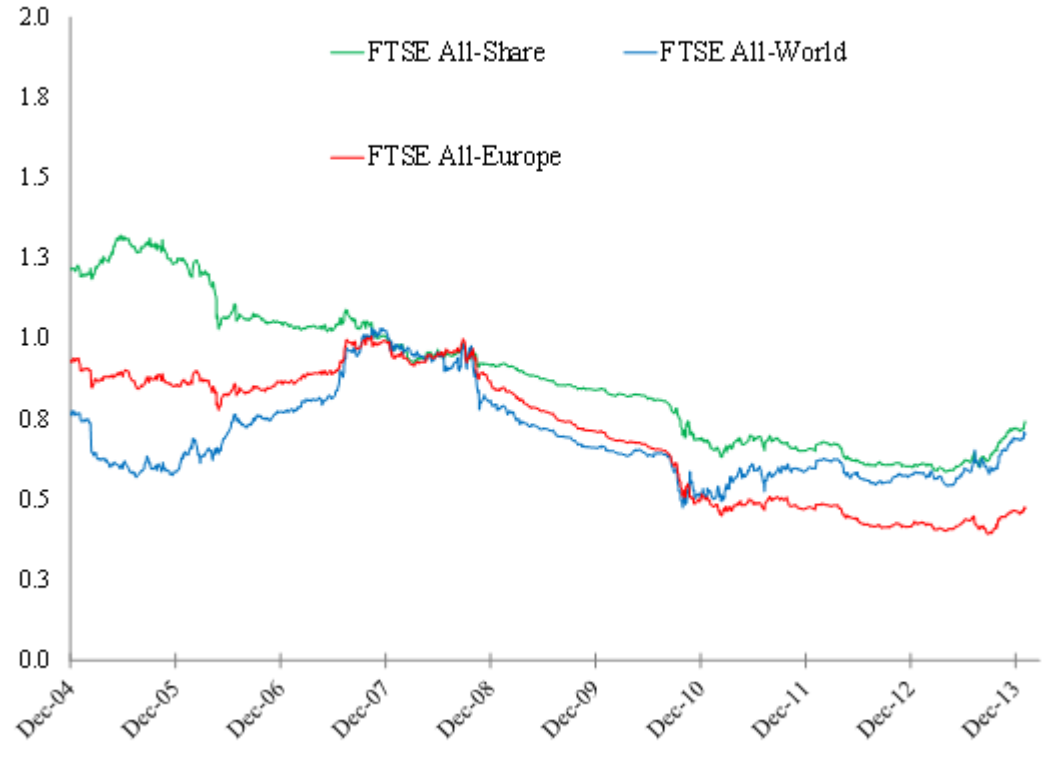


Figure 4 to Figure 9 plot one and two-year rolling equity betas for the other three parents for the UK MNOs against the FTSE All-Share, FTSE All-World and FTSE All-Europe. Both Telefonica and Orange's one-year and two-year equity betas have followed a sharp upward trend since mid-2010, and now stand at levels last seen during 2004 and 2005. In contrast, Deutsche Telekom's one-year and two-year equity betas have remained relatively stable over the past year, having increased sharply in mid-2011.

Figure 4: Deutsche Telekom rolling equity betas – one-year

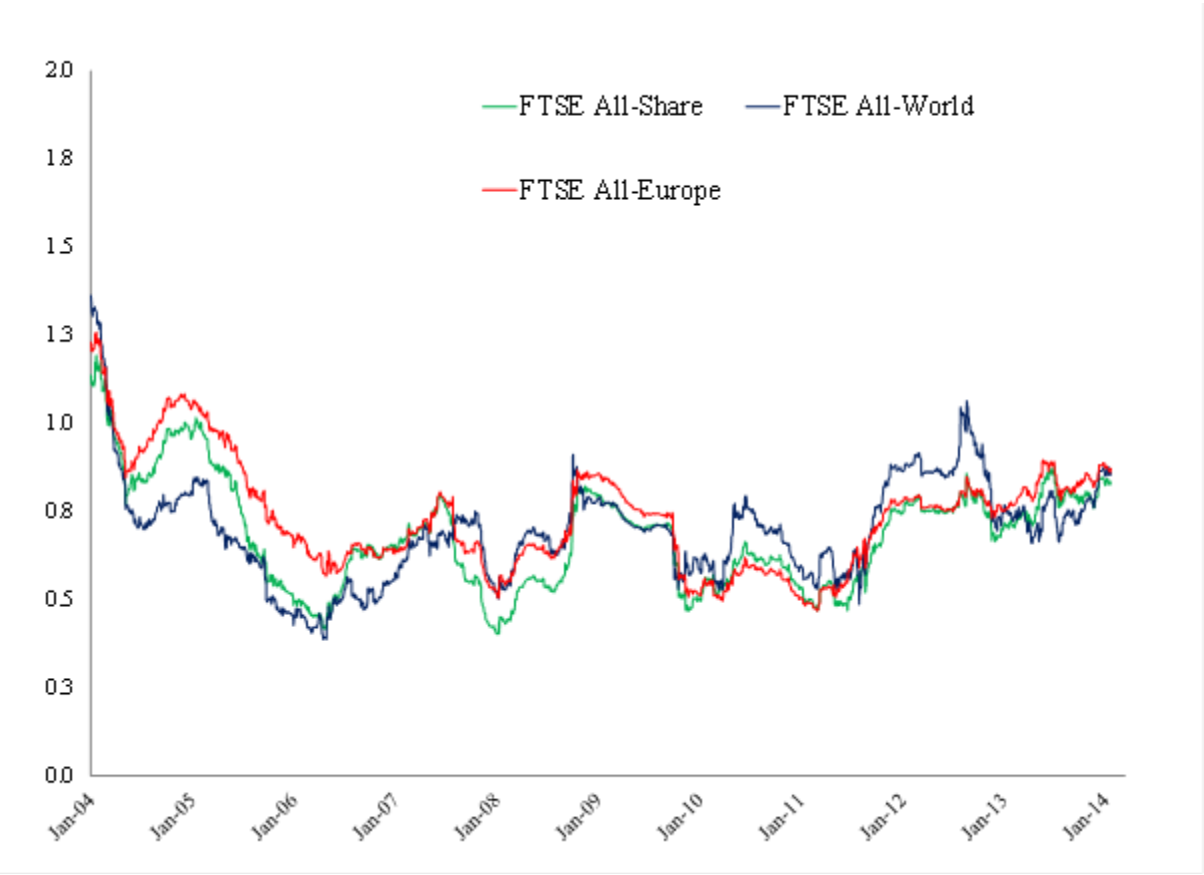


Figure 5: Deutsche Telekom rolling equity betas – two-year

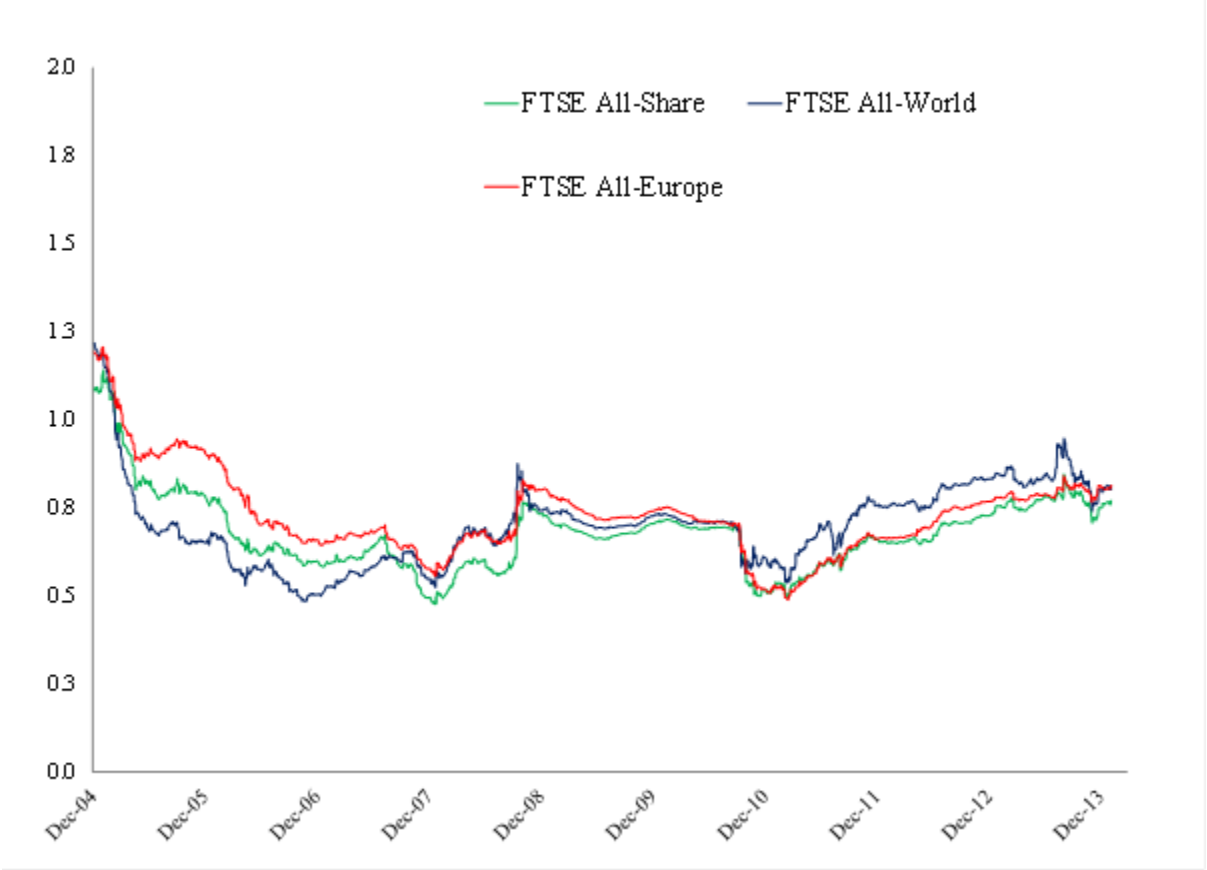


Figure 6: Orange rolling equity betas – one-year

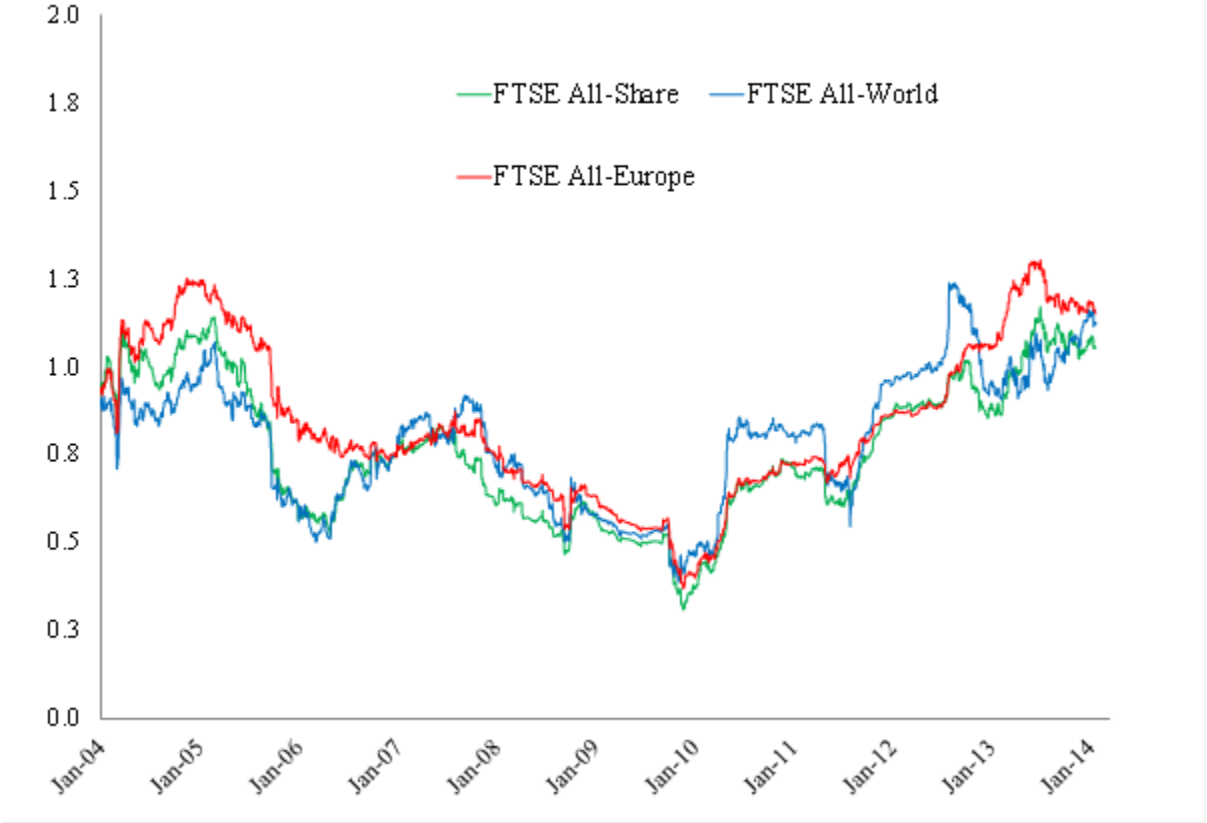


Figure 7: Orange rolling equity betas – two-year

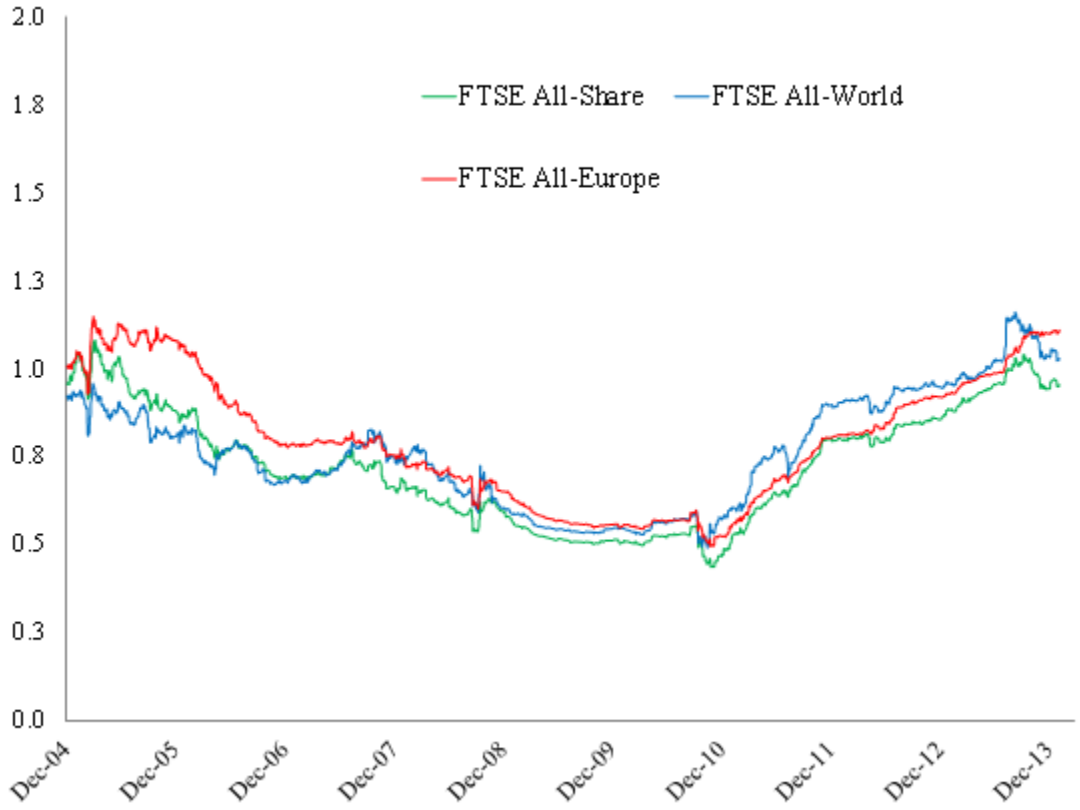


Figure 8: Telefonica rolling equity betas – one-year

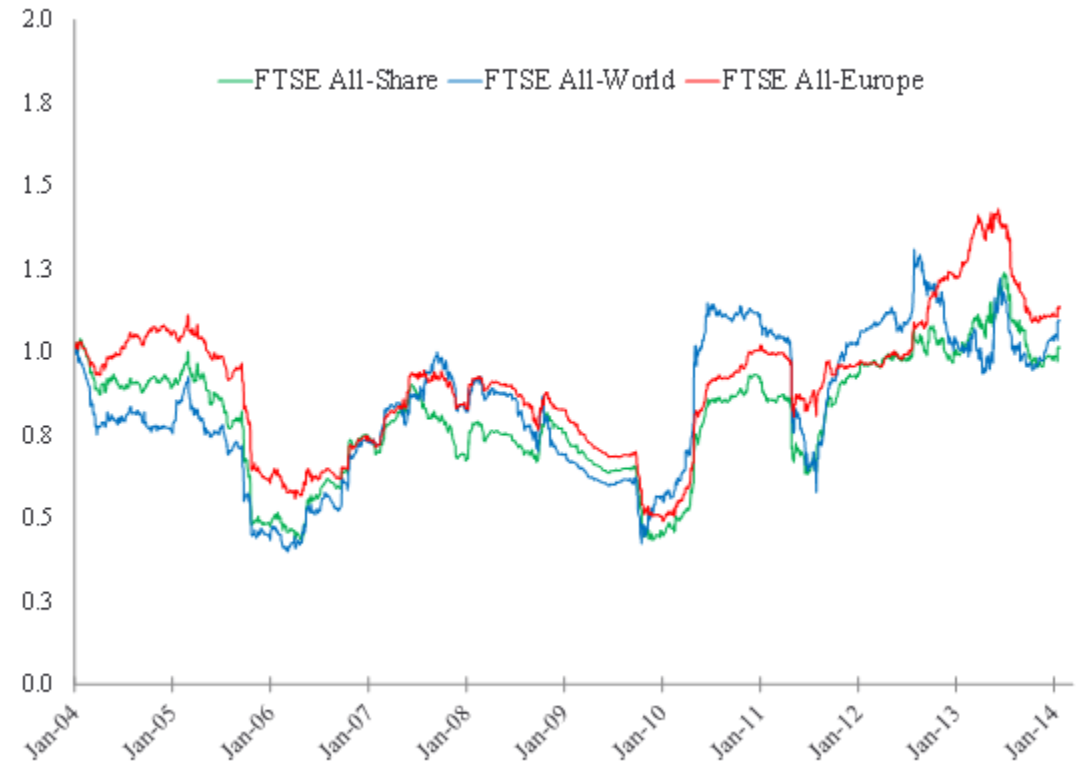
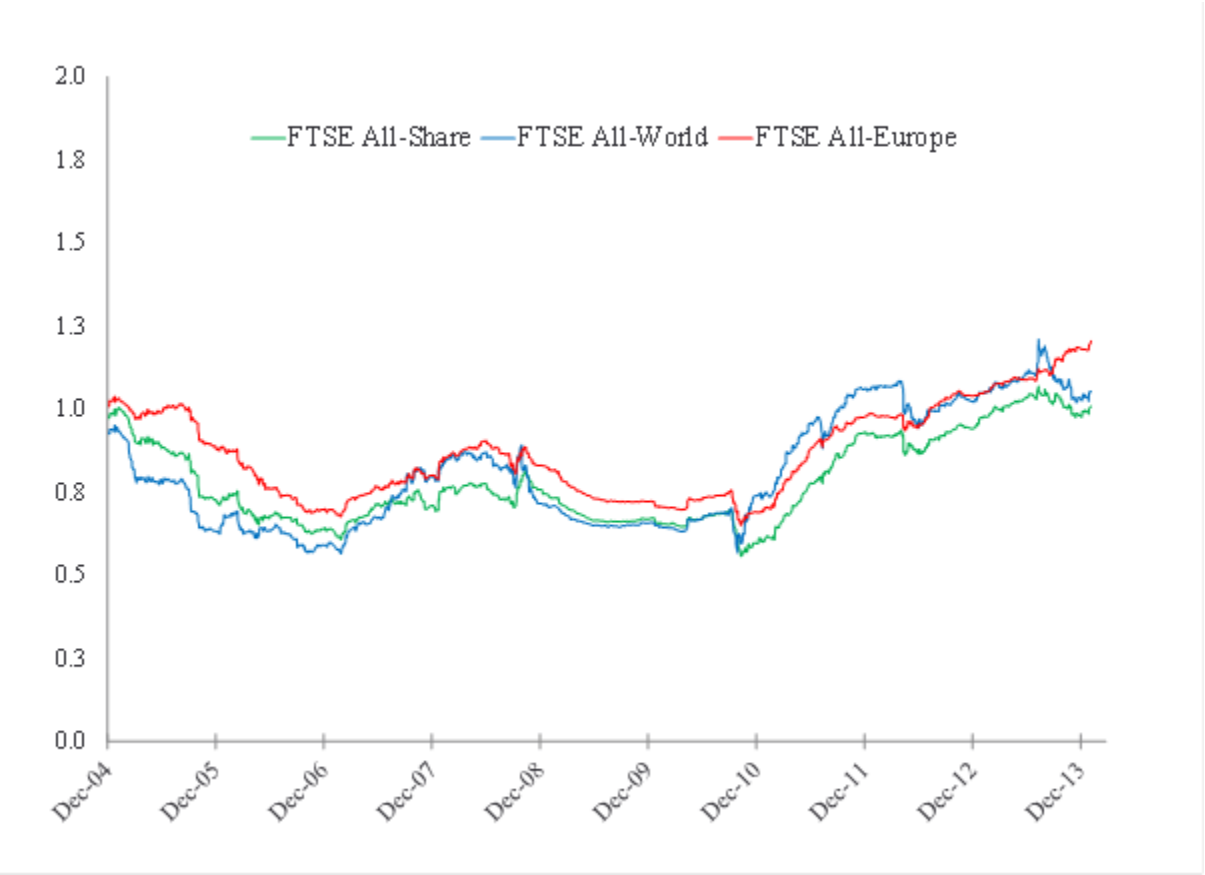


Figure 9: Telefonica rolling equity betas – two year



In Chapter III, we identify which particular data points exert the greatest influence on the one and two-year equity beta estimates and investigate the impact of those particular points on the estimates. We find that the standard OLS betas for Vodafone and the UK MNO parent companies are broadly robust to the exclusion or underweighting of influential data points.

II.A.2. Financial Leverage

Equity risk reflects the combination of underlying business risk (principally to do with the cyclicality of revenues and the extent of fixed costs) and financial risk (to do with the presence of fixed debt obligations). Other things equal, the more debt a company has outstanding, the greater the equity risk and the higher the equity beta. In general, extreme changes in financial leverage throughout the measurement window prompt the need for further analyses and checks.

We obtained data on the amount of debt outstanding for the four mobile network owners between 2000 and the present. We obtained data from company annual reports, half-yearly reports and quarterly earnings announcements. We supplement with data from Bloomberg. We use the available data to estimate the companies' capital structures at various points in time between 2000 and the present. In principle, we would use market values of both debt

and equity rather than book values, since market values better indicate earnings power. That being said, we follow the approach adopted in previous reports and assume that the market value of debt of the parent companies remained relatively close to its face value throughout the period in question. This assumption appears reasonable given that the parent companies of the four UK MNOs all maintained investment grade credit ratings throughout the measurement period.[6] We use the market value of equity.

We compute financial leverage in the same way as in our previous updates, with reference to the book value of outstanding debt and a working capital screen, rather than "net debt" which equals the book value of debt (and financial leases) less cash.[7] The use of the face value of outstanding debt and a working capital screen finds support in a leading corporate finance textbook.[8] First we compute working capital (current assets less current liabilities) for each company. If working capital is positive, analysts should zero out short-term debt and estimate financial leverage with reference to long-term debt only. But if working capital is negative, analysts should estimate financial leverage with reference to the sum of long-term plus short-term debt. For example, since current liabilities consistently exceed current assets (including cash) for all four parent companies, we end-up using the face value of both long-term and short-term debt in the leverage computation.[9]

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6 A possible concern is whether the market price of the mobile network owners' debt diverged somewhat from face value during the height of the credit crisis. If a significant market-to-book difference emerged, then a failure to use market values could bias, probably upward, our estimates of the companies' financial leverage. For example, as credit spreads spiked during the credit crisis, the price on Vodafone's debt may have declined somewhat, reflecting investors' concerns about the prospects for the UK and world economy. Incorporating the reduced market price of the debt in the calculation would reduce the appearance of financial leverage at Vodafone. Overstating leverage could lead us to effectively understate Vodafone's overall asset beta, since we would always expect leverage to add to the equity beta.

We check the potential impact of the financial crisis on financial leverage by estimating the market price of the mobile network owners' debt. A substantial portion of the mobile network owners' long-term debt is publicly traded. We obtained available data concerning debt prices and yields. The available data relates to debt currently outstanding and indicates that the market price of this debt has remained relatively close to its face-value since 2007. Market prices declined somewhat at the end of 2008 during the height of the crisis. Adjusting the amount of debt by less than 10% either way could have only a 2.5% impact on Vodafone's apparent leverage ratio, and even less on the average leverage over an extended measurement window.

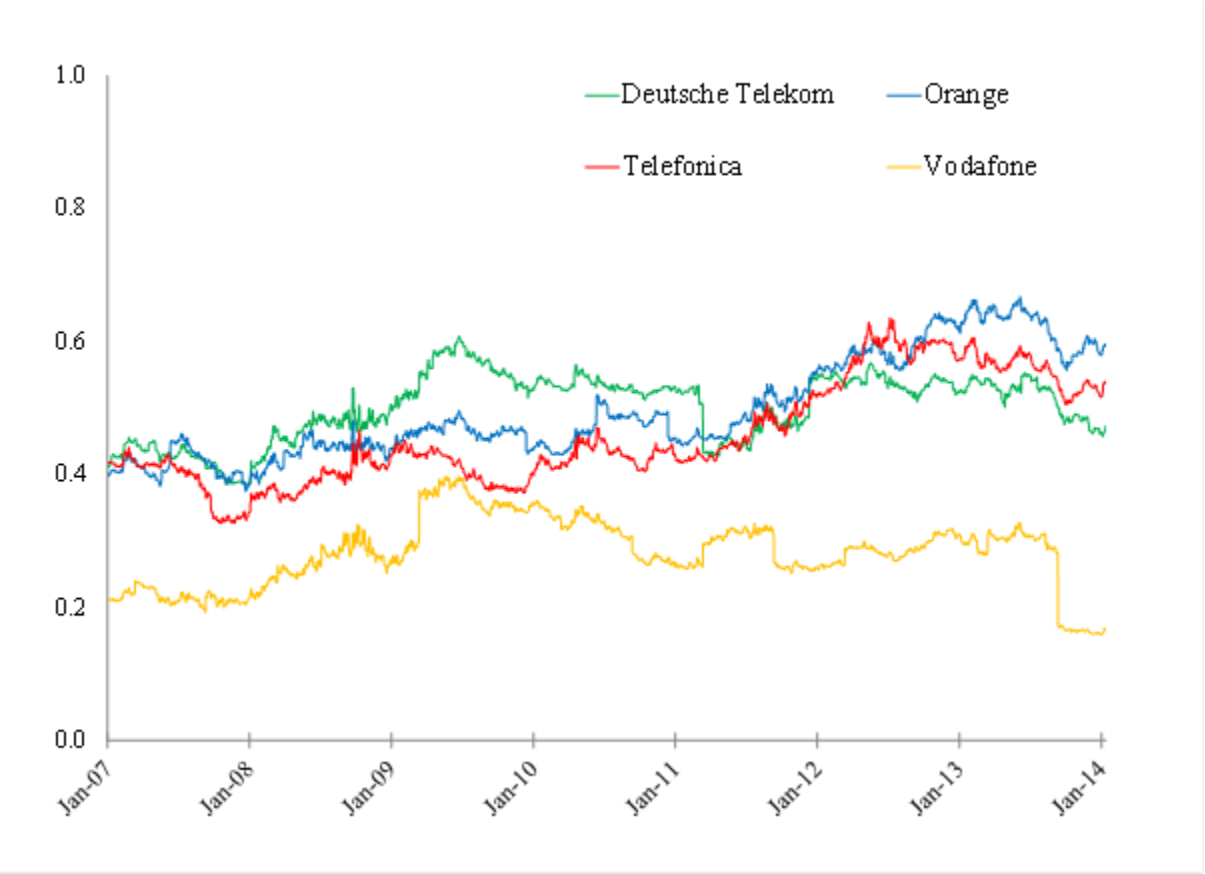
7 *See, for example,* Estimate of BT's Equity Beta (March 2014).

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

9 We also include financial leases in the leverage calculation.

Figure 10 plots our resulting estimates of financial leverage for the MNO parent company reference sample. The upward trend in Orange and Telefonica's equity betas since 2011 is correlated with an upward trend in their financial leverage. Deutsche Telekom's financial leverage has remained broadly flat since 2009, while Vodafone remains significantly less levered than the others. [10]

Figure 10: Financial leverage of UK MNO parent companies



II.A.3. Up-to-date Asset Beta Estimates

A further table and figures explore the effect of financial leverage on the observed equity betas of the four UK MNO parent companies. We use two separate approaches to re-lever the raw equity beta estimates. The first approach uses the simplest possible re-levering formula and assumes that the debt beta is zero.[11] The second approach is much the same as the first

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[10] At the end of 2013 Vodafone was preparing to sell Verizon and the related fixed asset was transferred to current assets as "current assets held for sale". Following the working capital screen, short term debt is no longer included in the leverage calculations which results in a drop in leverage for the third quarter of 2013. Verizon's sale was completed in February 2014.

[11] We use a standard relevering formula (see *Principles of Corporate Finance* (8th edition), Brealey Myers and Allen, p. 518): $\beta_a = \beta_e \times \left(\frac{E}{D+E}\right) + \beta_d \times \left(\frac{D}{D+E}\right)$, where β_a, β_e, and β_d represent

Continued on next page

but is more realistic in that it recognises some correlation between the returns to debt-holders and the broader economy. It assumes a debt beta of 0.10. Table 2 reports asset beta estimates under the two approaches. Under both approaches, we estimate average leverage across the relevant measurement window for the equity betas. In other words, when focusing on one-year equity betas, we estimate average leverage across the one-year measurement window. When focusing on two-year equity betas, we estimate average leverage across the two-year measurement window.

Table 2 confirms that the latest asset beta estimates for the four MNO parent companies remain in a relatively narrow band, and that two-year asset betas (assuming a debt beta of 0.1) across the four companies come in around 0.4 to 0.5, depending on the choice of market index. Vodafone's two-year asset beta against the FTSE All-Share, the FTSE All-World and Telefonica's two year asset beta against the FTSE All Europe are the principal exceptions at 0.56, 0.54, and 0.57 respectively. We might expect a small uplift for Vodafone against the FTSE All-Share in part because of its weighting in the FTSE All-Share itself.[12]

Figure 11 to Figure 14 then plot rolling one and two year asset betas for the four companies against the FTSE All-Share and against the FTSE All-World. They illustrate a) the relative volatility in the one-year asset betas over the past several years, particularly for Vodafone, b) the relative stability in the two-year betas, where we have seen an upward trend for Orange, Telefonica and Deutsche Telekom from late 2010 up to end 2011, but no significant movements thereafter, and c) the upward movement in Vodafone's two year asset betas during the past six months, while the two year asset betas of the other three companies have dropped slightly in the last six months.

Continued from previous page

asset beta, equity beta and debt beta respectively, and D and E represent the market values of outstanding debt and equity.

[12] According to the London Business School Risk Measurement Service publication for October to December 2013, the total market cap of the FTSE All-Share was close to £2.2 trillion. Vodafone's market cap was £105 billion, equivalent to just under 5% of the All-Share total. Vodafone was the second largest company by market capitalisation in the FTSE All-Share. Vodafone's 5% weighting in the FTSE All-Share raises the possibility of enhanced correlation and some uplift to the beta.

Table 2: UK MNO asset betas

	1 Yr		2 Yr	
	β debt = 0	*β debt = 0.1*	*β debt = 0*	*β debt = 0.1*
Deutsche Telekom				
All World	0.42	0.47	0.39	0.43
All Share	0.40	0.46	0.37	0.42
All Europe	0.42	0.47	0.39	0.44
Orange				
All World	0.43	0.49	0.39	0.47
All Share	0.40	0.46	0.36	0.43
All Europe	0.44	0.50	0.42	0.49
Telefonica				
All World	0.49	0.54	0.47	0.51
All Share	0.45	0.51	0.45	0.49
All Europe	0.50	0.56	0.53	0.57
Vodafone				
All World	0.56	0.59	0.52	0.54
All Share	0.67	0.70	0.55	0.56
All Europe	0.43	0.46	0.35	0.37
MNO Average				
All World	0.47	0.52	0.44	0.49
All Share	0.48	0.53	0.43	0.48
All Europe	0.45	0.50	0.42	0.47

Averages may vary due to rounding.

Figure 11: One-year asset betas against the FTSE All-Share

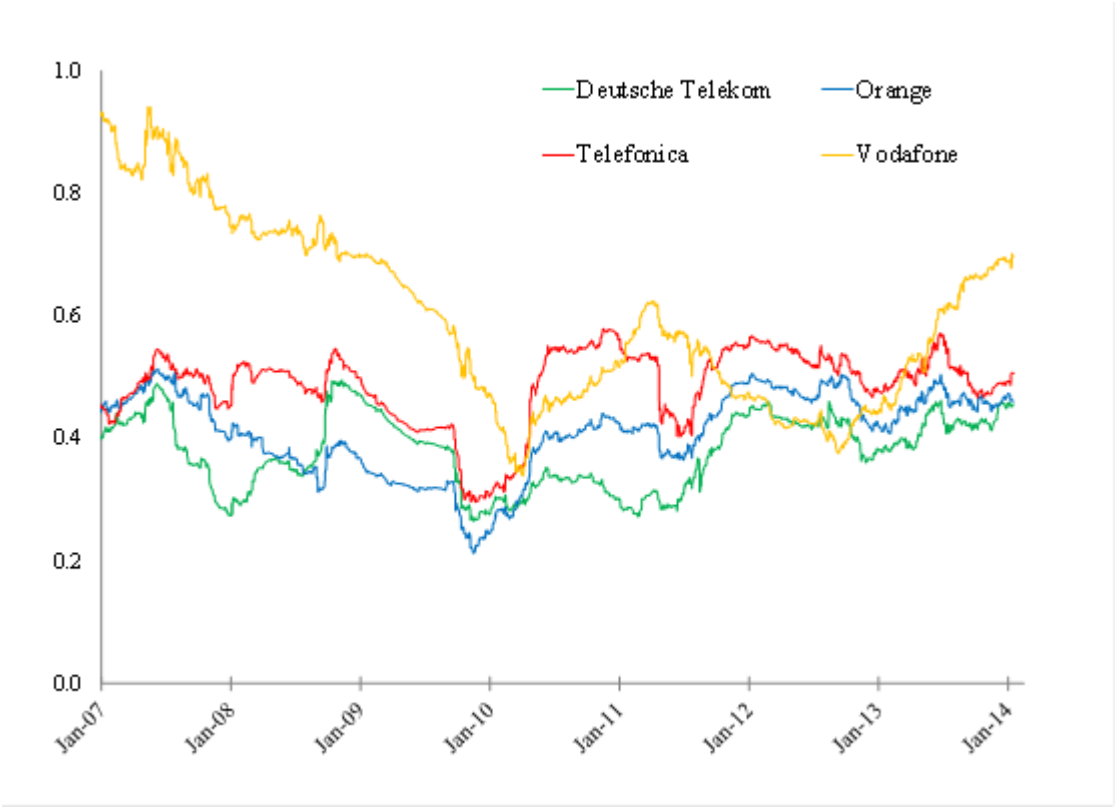


Figure 12: Two-year asset betas against the FTSE All-Share

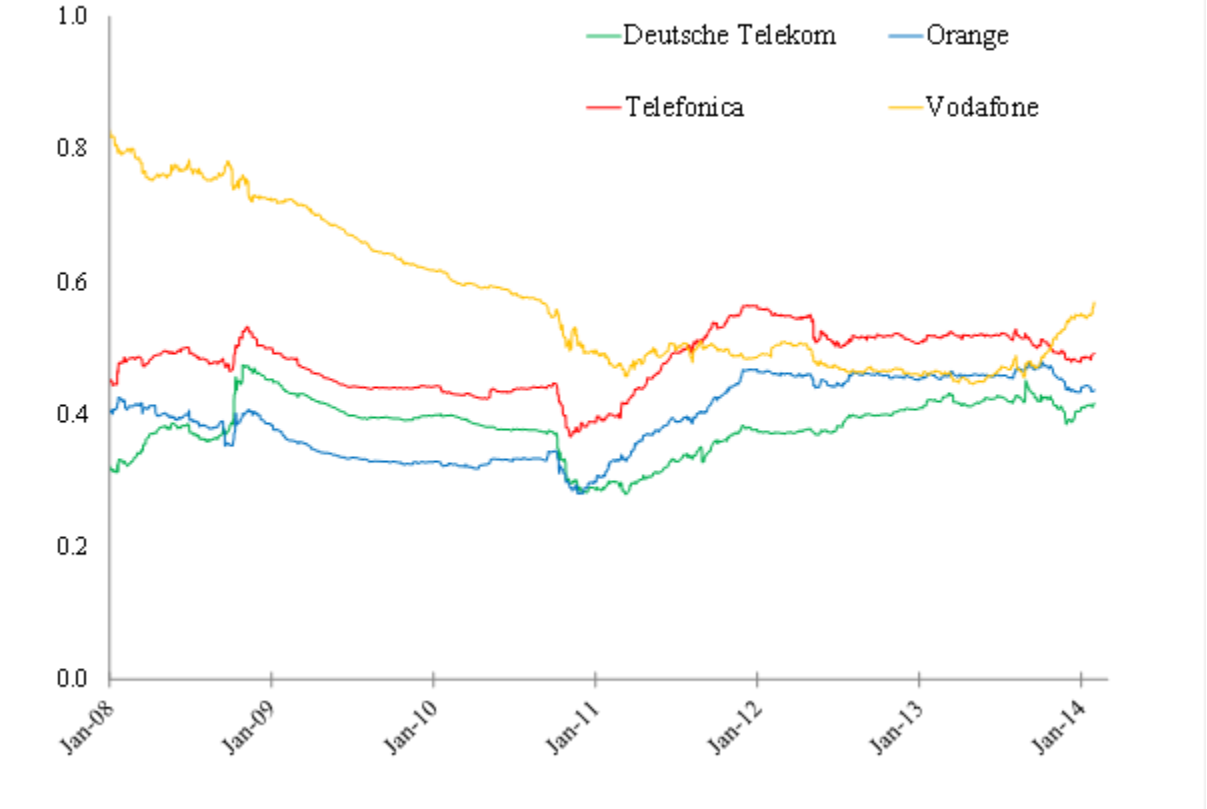


Figure 13: One-year asset betas against the FTSE All-World

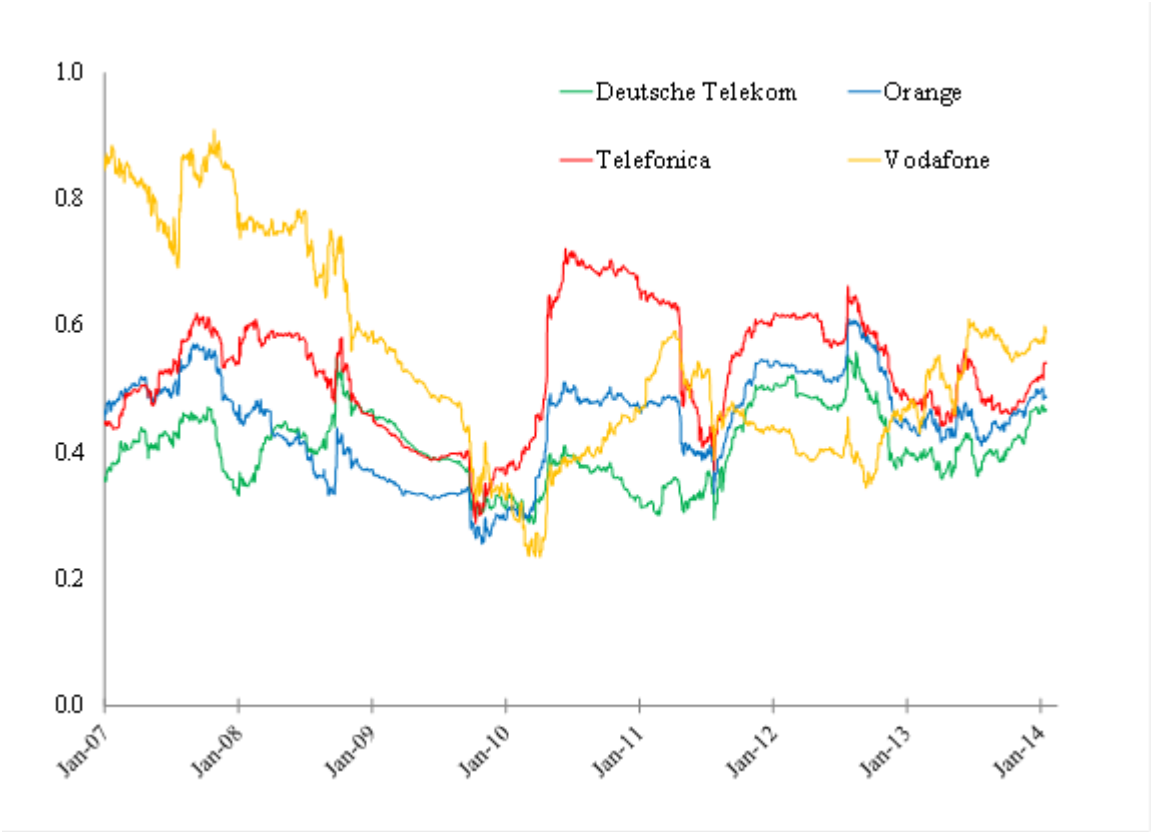


Figure 14: Two-year asset betas against the FTSE All-World

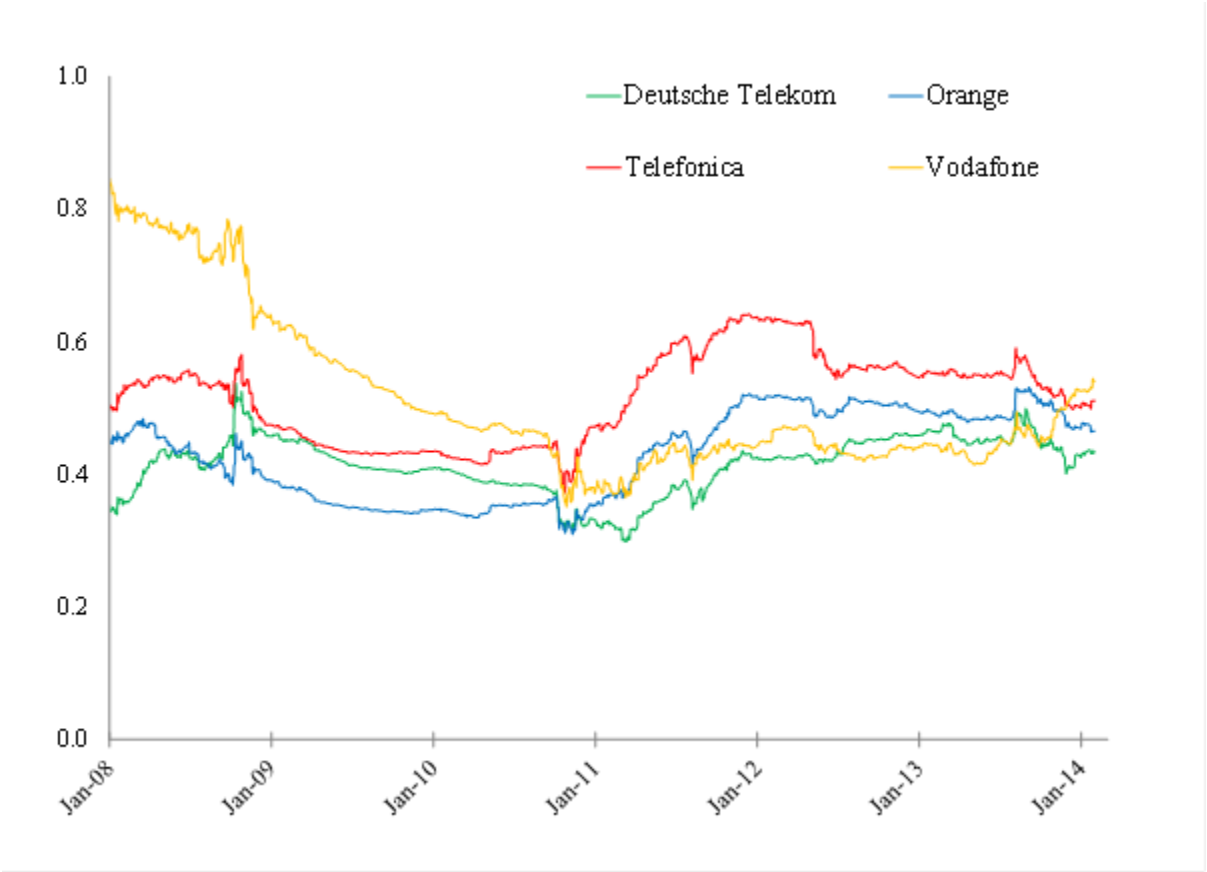


Table 3: Summary of Asset Betas for UK MNOs

	1 Yr		2 Yr	
	Range	Average	Range	Average
All World	0.47 to 0.59	0.52	0.43 to 0.54	0.49
All Share	0.46 to 0.70	0.53	0.42 to 0.56	0.48
All Europe	0.46 to 0.56	0.50	0.37 to 0.57	0.47

Note:
All figures above are for asset betas calculated assuming a debt beta of 0.1.

II.B. UK Utility Reference Sample

In addition to the UK MNO parent companies, we examined data for six UK utilities: National Grid (the gas and electricity transmission system operator), a further three water utilities (United Utilities, Severn Trent, and Pennon Group), and two other energy utilities, Centrica and SSE which combine regulated and unregulated activities. All of the companies in the UK utility peer group provide essential services and are subject to regulated price-caps, at least to some extent. A utility peer group subject to UK price regulation represents a useful peer group against which to compare the results of our equity and asset beta calculations for the UK MNOs and to assess their relative riskiness.

Using standard techniques, we estimated equity and asset betas for each of the six UK utility companies in Table 4 and Table 5 respectively.[13] Comparing Table 2 with Table 5 indicates that the average two year asset beta estimate (assuming debt beta of 0.1) for the UK MNO parent companies (0.47 to 0.49 depending on index) exceeds that for the UK utility peer group (0.34 to 0.35 depending on index). Figure 15 and Figure 16 then plot rolling one and two-year asset betas for the utility reference sample. They illustrate the relative stability of the utility asset betas for the period after pre-credit crisis data has dropped out of the data window. Asset betas for Centrica and SSE remain above the other regulated network companies.

[13] Like for the UK MNOs, we measured one-and two-year equity betas for the UK utility peer group against the FTSE All-Share, FTSE All-World and FTSE All-Europe indices. We computed daily returns for each company and the indices and applied standard ordinary least squares without adjustment. We then re-levered the observed OLS betas based on each company's average financial leverage across the one or two-year measurement window. We computed financial leverage based on the market value of equity and the book value of outstanding debt.

Table 4: UK utility equity betas

	1 Yr				2 Yr			
	Beta	SE	Low	High	Beta	SE	Low	High
National Grid								
All World	0.59	0.08	0.42	0.76	0.53	0.05	0.42	0.65
All Share	0.68	0.07	0.51	0.86	0.51	0.04	0.41	0.61
Pennon Group								
All World	0.50	0.09	0.33	0.68	0.51	0.07	0.36	0.65
All Share	0.50	0.08	0.35	0.64	0.52	0.06	0.39	0.62
Severn Trent								
All World	0.64	0.13	0.35	0.95	0.55	0.09	0.35	0.75
All Share	0.61	0.12	0.39	0.82	0.52	0.07	0.38	0.66
United Utilities								
All World	0.54	0.09	0.33	0.76	0.46	0.07	0.31	0.60
All Share	0.58	0.08	0.37	0.78	0.50	0.06	0.39	0.62
Centrica								
All World	0.41	0.10	0.23	0.60	0.48	0.07	0.36	0.62
All Share	0.55	0.09	0.38	0.72	0.57	0.05	0.46	0.67
Scottish & Southern Energy								
All World	0.57	0.08	0.41	0.73	0.55	0.06	0.44	0.66
All Share	0.64	0.07	0.50	0.77	0.56	0.05	0.47	0.64
UK Utility Peer Group Average								
All World	0.54				0.51			
All Share	0.59				0.53			

Note:
Diagnostic tests indicate the presence of either heteroskedascity or auto-correlation (or both) for the beta estimates of all companies against the two indices. We therefore report GLS betas for all companies.

Table 5: UK utility asset betas

	1 Yr		2 Yr	
	β debt = 0	*β debt = 0.1*	*β debt = 0*	*β debt = 0.1*
National Grid				
All World	0.32	0.36	0.28	0.33
All Share	0.37	0.41	0.27	0.31
Pennon Group				
All World	0.30	0.34	0.31	0.35
All Share	0.30	0.34	0.31	0.35
Severn Trent				
All World	0.31	0.37	0.27	0.32
All Share	0.30	0.35	0.25	0.31
United Utilities				
All World	0.24	0.29	0.20	0.26
All Share	0.25	0.31	0.22	0.28
Centrica				
All World	0.32	0.34	0.38	0.40
All Share	0.43	0.45	0.44	0.46
Scottish & Southern Energy				
All World	0.40	0.43	0.38	0.41
All Share	0.45	0.48	0.38	0.42
UK Utility Peer Group Average				
All World	0.32	0.36	0.30	0.34
All Share	0.35	0.39	0.31	0.35

Averages may vary due to rounding.

Figure 15: One-year asset betas for UK utility reference sample – Vs FTSE All-World

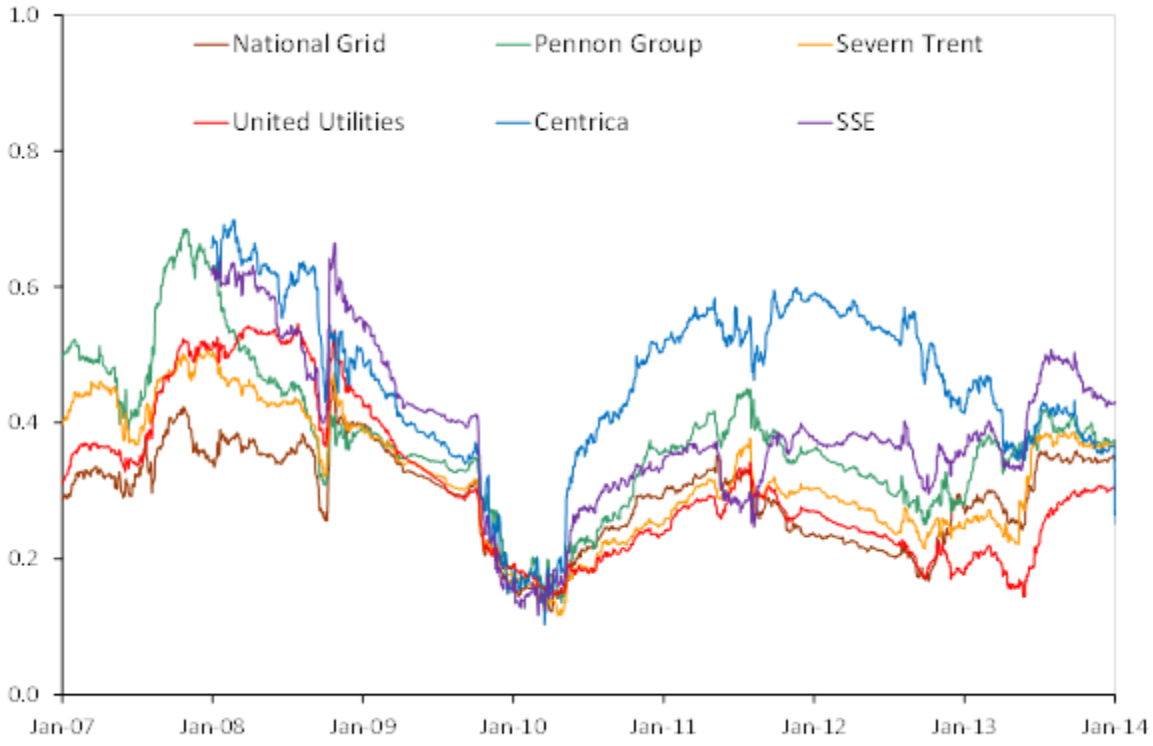


Figure 16: Two-year asset betas for UK utility reference sample – Vs FTSE All-World

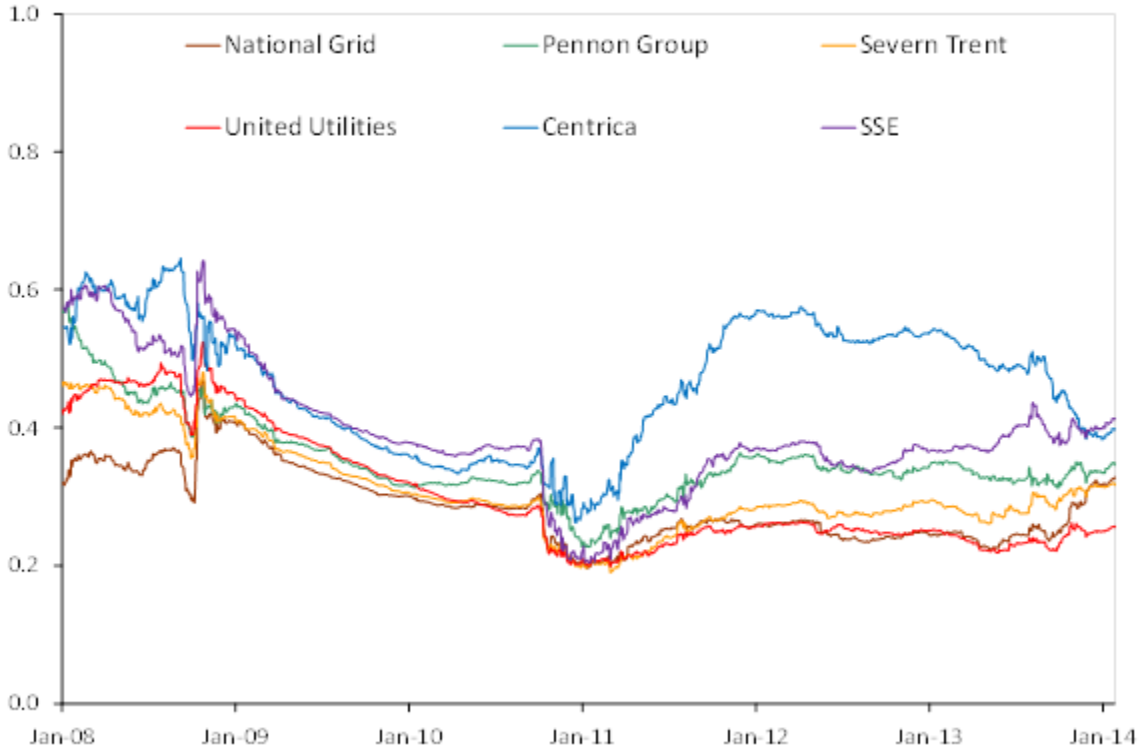


Table 6: Summary of Asset Betas for UK Utility Reference Sample

	1 Yr		2 Yr	
	Range	Average	Range	Average
All World	0.29 to 0.43	0.36	0.26 to 0.41	0.34
All Share	0.31 to 0.48	0.39	0.28 to 0.46	0.35

Note:
All figures above are for asset betas calculated assuming a debt beta of 0.1.

II.C. US TELECOMS SAMPLE

We also examined data for eleven US telecoms companies. Three of the companies were pure-play wireline (CenturyLink, Frontier, and Windstream), meaning that the core business of these companies involved local loop access and the provision of associated telephone services such as local telephone calls and retail broadband. Wireline activities accounted for just about half the revenues of AT&T, with wireless accounting for the remaining revenues. The majority of revenues come from wireless activities for six further companies (Verizon, Sprint, Leap, Clearwire, Metro PCS – now T-Mobile - TDS and US Cellular). Data for the US telecoms companies is relevant for our purpose to the extent that it reflects businesses whose principal activity is the provision of wireless services.

Several of our US sample have been acquired during the last year. Sprint was acquired by Softbank in July 2013. At the same time as the Softbank acquisition, Sprint acquired the remaining 50% of the shares in Clearwire that it did not already own. AT&T acquired Leap Wireless also in July 2013. T-Mobile purchased MetroPCS in May 2013, merging its existing operations with MetroPCS's. We include T-Mobile in our analysis, reflecting the new merged entity and MetroPCS prior to the merger.

We continue to include TDS and US Cellular separately in the sample, even though TDS is the majority owner of US Cellular, and US Cellular contributes the majority of TDS's earnings. Therefore, even though we begin by considering eleven US telecoms companies, we can compute an up-to-date beta for only nine of the companies.

Using the standard techniques, we estimated equity and asset betas for all of the US telecoms companies in Table 7 and Table 8 respectively. Figure 17 to Figure 18 then plot the development of the US Telecom asset betas over time. At present, the asset beta estimates for the pure-play fixed line companies – CenturyLink, Frontier and Windstream – come in slightly lower than those of the other companies where wireless activities account for at least

50% of earnings. The asset beta estimates for AT&T and Verizon have tracked those of CenturyLink, Frontier and Windstream for a sustained period, and have only broken away during the last six months. It remains to be seen whether this gap will persist.

The asset beta estimates for TDS and US Cellular are inextricably linked, and remained significantly above those of the other US companies after 2010. However, the asset betas for TDS and US Cellular have dropped over the last year. The one year asset betas are now comparable with those for AT&T and Verizon, while the two year asset betas are trending downward but still remain slightly above those for AT&T and Verizon.

Two year asset betas (assuming debt beta of 0.1) of the US companies with significant wireless earnings range from 0.40 and 0.69, with an average of 0.53 to 0.54 depending on the market index, and thus are consistent with the asset beta estimates for the UK MNO parent companies (average of 0.47-0.49 depending on the market index). We exclude Clearwire from the US wireless average because it was fully consolidated during 2013 and because it operates different wireless technology to others. We also exclude TDS to avoid double counting. A separate asset beta for TDS's major asset – US Cellular - already contributes to the US wireless average.

Table 7: US telecom equity betas

	1Yr				2 Yr			
	Beta	SE	Low	High	Beta	SE	Low	High
US Wireline								
Century Link								
SPX	0.80	0.17	0.46	1.13	0.66	0.09	0.50	0.83
All World	0.81	0.19	0.43	1.19	0.63	0.09	0.44	0.81
Frontier								
SPX	0.83	0.14	0.54	1.11	0.74	0.11	0.51	0.96
All World	0.81	0.17	0.48	1.14	0.66	0.13	0.39	0.92
Windstream								
SPX	0.81	0.10	0.61	1.02	0.78	0.08	0.62	0.94
All World	0.79	0.13	0.53	1.05	0.78	0.09	0.60	0.95
Average of US Wireline								
SPX	0.81				0.73			
All World	0.80				0.69			
AT&T								
SPX	0.70	0.07	0.56	0.83	0.66	0.05	0.57	0.75
All World	0.67	0.08	0.50	0.84	0.58	0.06	0.46	0.69
Clearwire								
SPX	0.81	0.46	-0.09	1.70	0.82	0.32	0.19	1.45
All World	1.14	0.46	0.24	2.04	0.91	0.33	0.26	1.56
Leap Wireless								
SPX	1.10	0.28	0.55	1.65	1.86	0.29	1.28	2.44
All World	1.44	0.34	0.76	2.12	1.91	0.33	1.27	2.55
Sprint								
SPX	1.21	0.15	0.91	1.50	1.43	0.16	1.13	1.74
All World	1.25	0.17	0.92	1.57	1.43	0.16	1.10	1.75
TDS								
SPX	0.92	0.12	0.68	1.16	1.08	0.16	0.77	1.38
All World	1.07	0.13	0.81	1.34	1.05	0.13	0.79	1.32
T-Mobile								
SPX	0.92	0.17	0.58	1.27	1.16	0.21	0.76	1.57
All World	0.84	0.27	0.30	1.37	1.24	0.27	0.70	1.78
US Cellular								
SPX	0.63	0.11	0.40	0.85	0.72	0.13	0.47	0.97
All World	0.69	0.13	0.42	0.95	0.71	0.12	0.48	0.94
Verizon								
SPX	0.64	0.09	0.47	0.81	0.60	0.05	0.50	0.71
All World	0.65	0.09	0.47	0.82	0.54	0.06	0.43	0.65
Average of US Wireless (excl Clearwire, TDS)								
SPX	0.87				1.07			
All World	0.92				1.07			

Note:
We report OLS betas except where diagnostic tests indicate the presence of either heteroskedascity or auto-correlation. In which case we report GLS betas. We identified autocorrelation or heteroskedasacity for the one and two year equity betas of Leap Wireless, Sprint, TDS, T-Mobile, US Cellular, Verizon and Windstream against the FTSE All-World and the SP500. We also identified autocorrelation or heteroskedasacity for the two year equity betas of AT&T, Clearwire and Frontier against the FTSE All-World and the SP500.

Table 8: US telecom asset betas

	1 Yr		2 Yr	
	β debt = 0	β debt = 0.1	β debt = 0	β debt = 0.1
US Wireline				
Century Link				
SPX	0.39	0.44	0.34	0.39
All World	0.40	0.45	0.32	0.37
Frontier				
SPX	0.29	0.35	0.25	0.32
All World	0.28	0.35	0.23	0.29
Windstream				
SPX	0.29	0.36	0.30	0.36
All World	0.29	0.35	0.30	0.36
Average of US Wireline				
SPX	0.32	0.38	0.30	0.36
All World	0.32	0.38	0.28	0.34
US Wireless				
AT&T				
SPX	0.50	0.53	0.49	0.51
All World	0.48	0.51	0.43	0.45
Clearwire				
SPX	0.44	0.49	0.34	0.40
All World	0.62	0.67	0.38	0.44
Leap Wireless				
SPX	0.23	0.31	0.32	0.40
All World	0.29	0.37	0.33	0.41
Sprint				
SPX	0.56	0.61	0.58	0.64
All World	0.58	0.63	0.58	0.64
TDS				
SPX	0.56	0.60	0.66	0.70
All World	0.66	0.70	0.64	0.68
T-Mobile				
SPX	0.62	0.66	0.60	0.65
All World	0.56	0.60	0.65	0.69
US Cellular				
SPX	0.50	0.52	0.57	0.59
All World	0.55	0.57	0.55	0.58
Verizon				
SPX	0.44	0.47	0.42	0.45
All World	0.45	0.48	0.38	0.41
Average of US Wireless (excl Clearwire, TDS)				
SPX	0.47	0.52	0.47	0.54
All World	0.50	0.53	0.47	0.53

Averages may vary due to rounding.

Figure 17: One-year asset betas for US telecom reference sample – Vs FTSE All-World

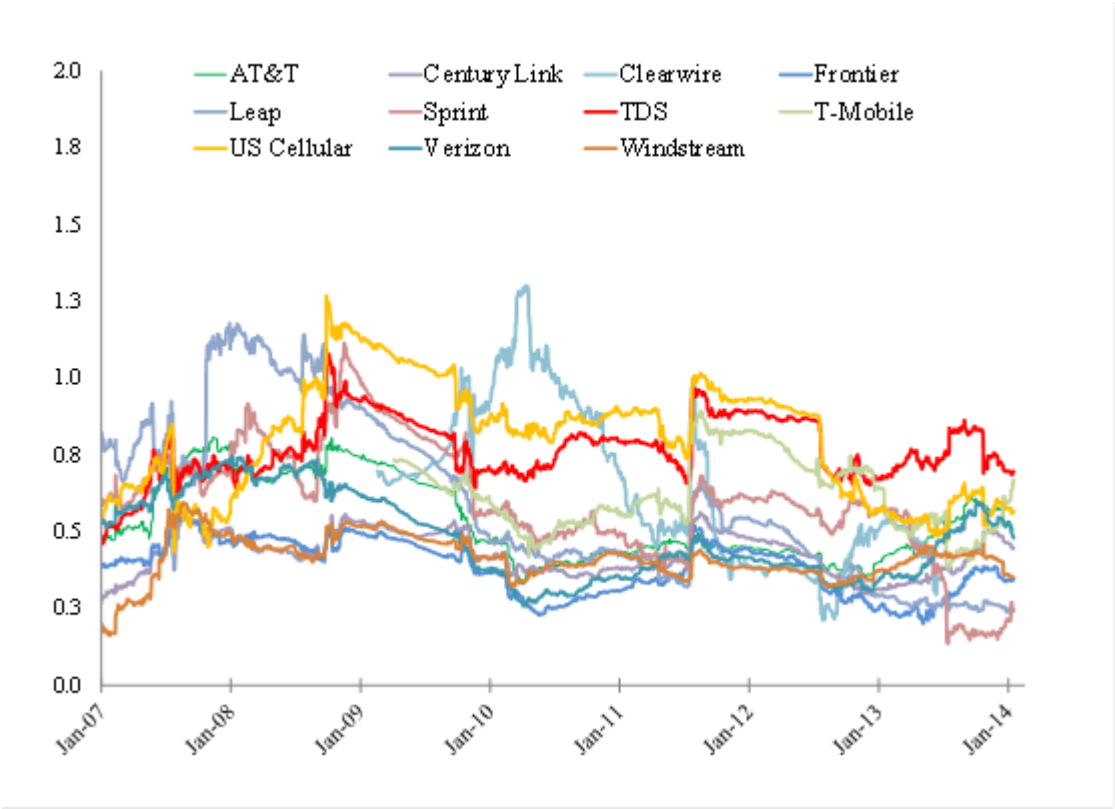


Figure 18: Two-year asset betas for US telecom reference sample – Vs FTSE All-World

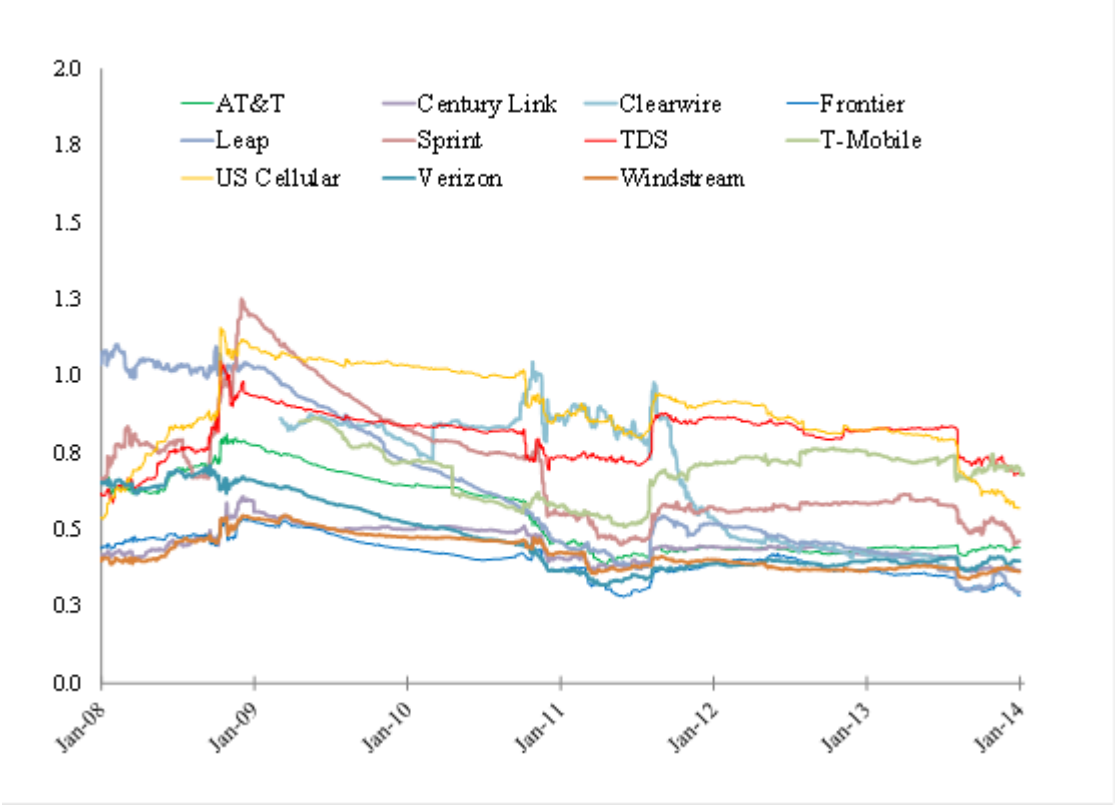


Table 9: Summary of Asset Beta Range for US Telecom Sample

	1 Yr		2 Yr	
	Range	Average	Range	Average
US Wireline				
SPX	0.35 to 0.44	0.38	0.32 to 0.39	0.36
All World	0.35 to 0.45	0.38	0.29 to 0.37	0.34
US Wireless (excl Clearwire, TDS)				
SPX	0.31 to 0.66	0.52	0.40 to 0.65	0.54
All World	0.37 to 0.63	0.53	0.41 to 0.69	0.53

Note:
All figures above are for asset betas calculated assuming a debt beta of 0.1.

II.D. EU TELECOMS SAMPLE

We also examined data for eight EU telecoms companies, in addition to the parent companies of the UK MNOs. Like for the US sample, the EU companies are engaged in both wireline and wireless activities. Four of the companies are incumbent network operators with diversified operations across wireless and wireline: Belgacom (about 16% of revenues from mobile communications in 2013) KPN (about 75% of revenues from wireless in 2013), Telenor (about 78% of revenues from wireless in 2013) and Telecom Italia (about 24% of revenues from mobile in 2013). Two further companies derive more than two thirds of revenues from mobile services: Mobistar which offers mobile network services in Belgium (about 87% of revenues from mobile in 2013), and Tele2 which offers mobile services in Sweden and a range of other European countries (more than 70% of revenues from mobile in 2013). The penultimate company in our EU sample is Drillisch, a re-seller of mobile network services in Germany. The final company is Sonaecom, which offers fixed and wireless services from a base in Portugal. Sonaecom derives about 60% of its revenues from mobile services, and the remainder from fixed line and TV.

We segregate our EU sample into two sub samples: "EU wireless" comprising firms that derive more than two thirds of their revenues from mobile (KPN, Mobistar, Telenor and Tele2), "EU diversified" comprising firms offering a spread of services including mobile (Belgacom, Telecom Italia and Sonaecom). We consider Drillisch in a category by itself, reflecting the distinction between its business model and those of the other firms.

Using the standard techniques, we estimated equity and asset betas for all of the EU telecoms companies in Table 10 and Table 11 respectively. Figure 19 and Figure 20 plot the development of the asset betas over time.

Two-year asset beta estimates (assuming debt beta of 0.1) for the three diversified companies range from 0.36 to 0.45, with an average of 0.41 to 0.42 depending on market index.

Two-year asset beta estimates (assuming debt beta of 0.1) for the four firms deriving more than two thirds of revenues from mobile range from 0.32 to 0.69 and average around 0.49-0.51 depending on market index, a shade higher than for the three diversified companies. Two-year asset beta estimates for KPN consistently come in below average, while Telenor has consistently posted two-year asset betas above 0.5. Mobistar's two-year asset beta has trended upwards since 2011 and after recording a slight decrease in the past few months now stands close to 0.5 and the average level ofthe EU wireless sample. At the same time, while Tele2's two-year asset beta has trended downwards since mid-2012, it remains above those for other EU wireless comparators.

Both the one and two-year asset beta estimates for Drillisch are significantly higher than for any of the other EU telecoms companies. Drillisch's one-year asset beta has risen sharply over the last six months and now stands just above 1.0. Its two-year beta has dropped since mid-2013, recovering recently to around the 0.9 level. As a re-seller of mobile network services, Drillisch's business model remains somewhat distinct from any of the other companies. It remains possible that Drillisch's particular business model could expose it to additional risks, which would not be present for traditional network operators. For example, we would expect Drillisch's operating leverage to be somewhat higher than would be the case for traditional mobile network companies.[14]

[14] Traditional mobile network operators invested significant sums in the past. Network revenues now reflect compensation for both operating expenses and a return of and on historical capital investment. In contrast, Drillisch purchases network services from the traditional network operations, and must compensate the network operators for their past investment as well as operating costs. It then captures a retail margin, which we would expect to reflect the costs of retailing network services. The implication is that Drillisch is likely to report higher operating leverage (operating costs as a % of revenues) than the network operations. In turn, higher operating leverage is often associated with higher risk and asset betas.

Table 10: EU telecom equity betas

	1 Yr				2 Yr			
	Beta	SE	Low	High	Beta	SE	Low	High
EU Diversified								
Belgacom								
All World	0.55	0.12	0.31	0.79	0.55	0.08	0.39	0.70
All Europe	0.55	0.09	0.38	0.73	0.56	0.05	0.46	0.66
Sonaecom								
All World	0.59	0.14	0.31	0.88	0.64	0.09	0.45	0.82
All Europe	0.72	0.14	0.44	1.00	0.61	0.08	0.46	0.76
Telecom Italia								
All World	1.24	0.23	0.79	1.69	1.05	0.17	0.71	1.38
All Europe	1.27	0.18	0.90	1.63	1.19	0.11	0.97	1.42
Average of EU Diversified								
All World	0.79				0.74			
All Europe	0.85				0.79			
EU Wireless								
KPN								
All World	1.02	0.22	0.57	1.46	0.71	0.16	0.40	1.03
All Europe	0.80	0.18	0.45	1.16	0.63	0.12	0.39	0.87
Mobistar								
All World	0.64	0.15	0.35	0.94	0.60	0.12	0.38	0.83
All Europe	0.69	0.12	0.45	0.92	0.62	0.09	0.45	0.80
Telenor								
All World	0.67	0.12	0.43	0.91	0.70	0.09	0.53	0.86
All Europe	0.73	0.09	0.55	0.91	0.67	0.06	0.56	0.79
Tele2								
All World	0.81	0.14	0.54	1.08	0.87	0.10	0.68	1.06
All Europe	0.77	0.12	0.54	1.00	0.74	0.07	0.60	0.88
Average of EU Wireless								
All World	0.79				0.72			
All Europe	0.75				0.67			
EU Other								
Drillisch								
All World	1.19	0.13	0.93	1.46	1.18	0.11	0.97	1.39
All Europe	1.16	0.11	0.94	1.37	1.00	0.07	0.86	1.14

Note:
Diagnostic tests indicate the presence of either heteroskedascity or auto-correlation (or both) for the beta estimates of all companies against the two indices. We therefore report GLS betas.

Table 11: EU telecom asset betas

	1 Yr		2 Yr	
	β debt = 0	*β debt = 0.1*	*β debt = 0*	*β debt = 0.1*
EU Diversified				
Belgacom				
All World	0.41	0.44	0.43	0.45
All Europe	0.42	0.44	0.42	0.45
Sonaecom				
All World	0.42	0.45	0.39	0.43
All Europe	0.53	0.56	0.38	0.42
Telecom Italia				
All World	0.31	0.39	0.28	0.36
All Europe	0.32	0.40	0.32	0.39
Average of EU Diversified				
All World	0.38	0.43	0.37	0.41
All Europe	0.42	0.47	0.38	0.42
EU Wireless				
KPN				
All World	0.36	0.43	0.27	0.33
All Europe	0.32	0.38	0.25	0.32
Mobistar				
All World	0.43	0.46	0.44	0.47
All Europe	0.45	0.49	0.46	0.48
Telenor				
All World	0.53	0.55	0.55	0.57
All Europe	0.57	0.59	0.54	0.56
Tele2				
All World	0.62	0.64	0.66	0.69
All Europe	0.58	0.60	0.56	0.59
Average of EU Wireless				
All World	0.48	0.52	0.48	0.51
All Europe	0.48	0.51	0.45	0.49
EU Other				
Drillisch				
All World	1.03	1.04	0.91	0.93
All Europe	1.00	1.02	0.77	0.79

Averages may vary due to rounding.

Figure 19: One-year asset betas for EU telecom reference sample – Vs FTSE All-World

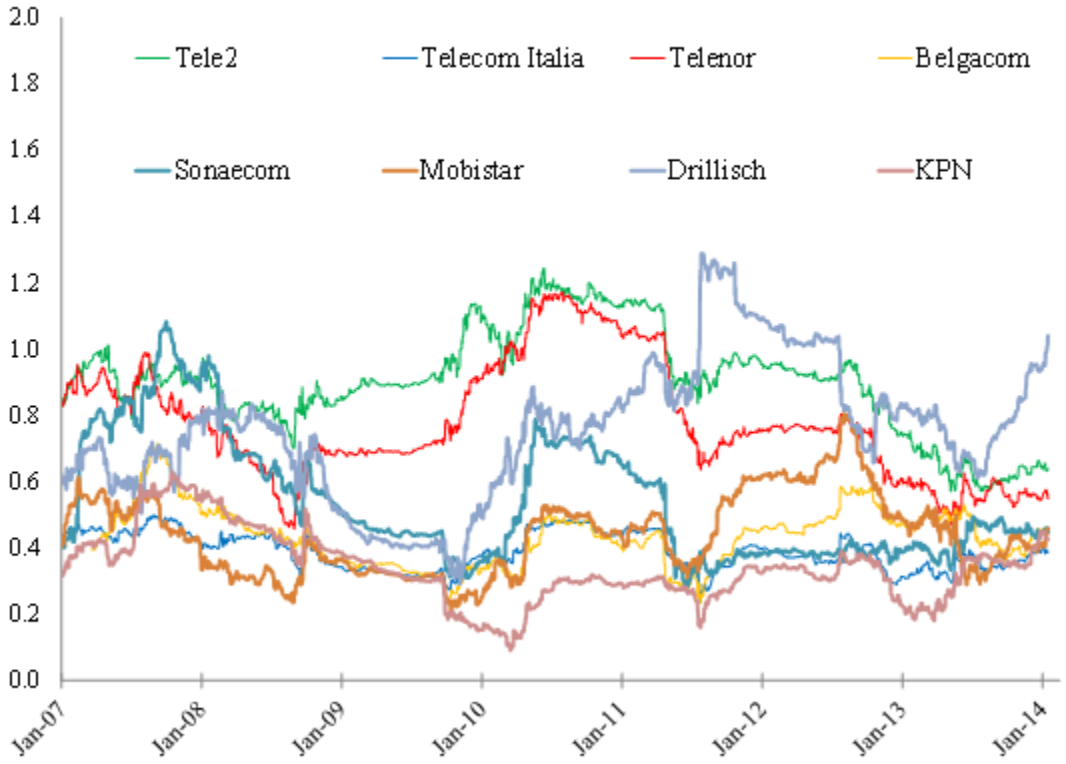


Figure 20: Two-year asset betas for EU telecom reference sample – Vs FTSE All-World

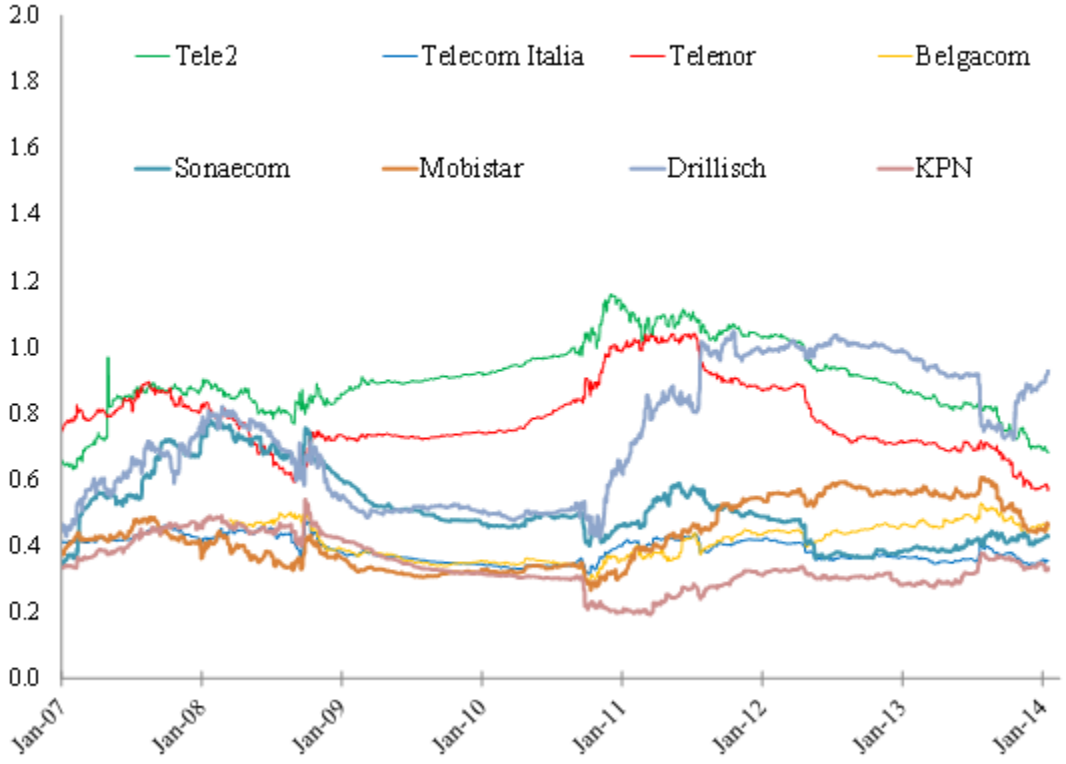


Table 12: Summary of Asset Beta for EU Telecom Sample

	1 Yr		2 Yr	
	Range	Average	Range	Average
EU Diversified				
All World	0.39 to 0.45	0.43	0.36 to 0.45	0.41
All Europe	0.40 to 0.56	0.47	0.39 to 0.45	0.42
EU Wireless				
All World	0.43 to 0.64	0.52	0.33 to 0.69	0.51
All Europe	0.38 to 0.60	0.51	0.32 to 0.59	0.49

Note:
All figures above are for asset betas calculated assuming a debt beta of 0.1.

II.E. Conclusions

The best current estimates for the two-year equity betas of the parent companies of the UK MNOs are:

- 0.81 for Deutsche Telekom. We normally recommend a range of +/- approximately two standard deviations around these mid-point figures—ie, a range of 0.64-0.97 in this case. Given average leverage of 53% over the past two years and assuming a debt beta of 0.1, these figures translate into a range for the asset beta of between 0.36 and 0.51.
- 1.03 for Orange, and 95% confidence interval of 0.81-1.24. Given average leverage of 61% over the past two years and assuming a debt beta of 0.1, these figures translate into a range for the asset beta of between 0.38 and 0.55.
- 1.05 for Telefonica, and 95% confidence interval of 0.84-1.26. Given average leverage of 57% over the past two years and assuming a debt beta of 0.1, these figures translate into a range for the asset beta of between 0.42 and 0.60.
- 0.70 for Vodafone, and 95% confidence interval of 0.56-0.85. Given average leverage of 27% over the past two years and assuming a debt beta of 0.1, these figures translate into a range for the asset beta of between 0.43 and 0.65, again depending on an assumption about debt beta.

We report two-year betas against the FTSE All-World because i) none of the companies represents a significant % of the All-World index by market capitalization, ii) all four companies pull substantial investment from all corners of the globe, and iii) all four companies have significant operations spread across the globe.

The two-year asset beta estimates for the four UK MNO's against the FTSE All-World currently stand in a relatively narrow band between 0.43 and 0.54 (assuming a debt beta of 0.1)[15]. Vodafone's asset beta estimates against the FTSE All-World tend to exceed 0.5 and are currently the highest among the parent companies of the UK MNOs. Vodafone's one year asset betas against both FTSE All-Share and FTSE All-World have been trending up over the past year, while the two year estimates have been trending upwards over the past six months. Seven of 11 companies[16], where wireless accounts for more than two thirds of revenues, display two-year asset betas against the FTSE All-World above 0.5.

Table 13 compares asset beta ranges and averages for each of our samples. The table reports asset betas against the FTSE All-World with the debt beta equal to 0.1. The average two-year asset betas for the parent companies of the UK MNOs stand around 0.50, somewhat higher than the average two-year asset betas for our UK utility reference sample (0.34) and for US fixed line telecom companies (0.34), but broadly comparable to telecom companies in the US and Europe with a significant mobile focus (0.53 and 0.51 respectively).

Table 13: Summary of Asset Beta Ranges

	1 Yr		2 Yr	
	Range	Average	Range	Average
UK MNO	0.47 to 0.59	0.52	0.43 to 0.54	0.49
UK Utilities	0.29 to 0.43	0.36	0.26 to 0.41	0.34
US Wireline	0.35 to 0.45	0.38	0.29 to 0.37	0.34
US Wireless	0.37 to 0.63	0.53	0.41 to 0.69	0.53
EU Diversified	0.39 to 0.45	0.43	0.36 to 0.45	0.41
EU Wireless	0.43 to 0.64	0.52	0.33 to 0.69	0.51

Note:
All figures above are for asset betas calculated against FTSE All World and assuming a debt beta of 0.1.

Based on this evidence, we recommend an asset beta range of 0.4 to 0.6 for an efficient UK MNO. Our recommended range is consistent with the asset betas of the parent companies of the UK MNOs themselves, with particular weighting towards the estimated asset beta ranges for Vodafone and Telefonica as the two parent companies with the greatest overall

[15] The UK MNOs average beta estimate against the FTSE All-Share is very close to the average observed against the FTSE All-World both for the one-year and the two-year betas. The range for the two-year asset beta estimates against the FTSE All-Share is 0.42 to 0.56 .

[16] Vodafone, Telefonica, Sprint, T-Mobile, US Cellular, Telenor and Tele2 get around two thirds or more of their revenue from wireless and have asset betas higher than 0.5. The other companies with more than two thirds of mobile revenues are Leap, Verizon, KPN and Mobistar. With the exception of KPN, asset betas for these companies tend to be lower than 0.5 but higher than 0.4.

focus on mobile operations. The recommended range reflects the statistical uncertainty inherent in our two-year asset beta estimates (see discussion above). Our recommended asset beta range also is consistent with both US and European telecom companies displaying a significant mobile focus. Almost all of the sample companies display asset betas within or close to the range.

III. 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.[17] We perform a number of statistical tests to check for potential problems in this case. Below we report the results of our statistical tests for the parent companies of the UK MNOs. We performed exactly the same tests for the betas computed above for the companies in the three reference samples. We confirm the statistical robustness of all of the betas presented in Chapter II of this report.

III.A. DIMSON ADJUSTMENT

To test for possible bias relating to trading illiquidity and to assess if time differences[18] caused distortions, we perform the "Dimson" adjustment to the estimated betas by including a one period lag and a one period lead. For the four UK MNOs, one out of 24 lead terms was significantly different from zero (one-year equity betas for Orange against the FTSE All-Share). No lag term was statistically significant. In no case were the Dimson adjustments overall significantly different from zero. A similar picture emerges for the US Telecom sample, where none of the Dimson adjustments are significant. For the UK utility sample three out of the 28 lag adjustments and two out of 28 lead adjustments are significant. The EU telecoms sample has only two out of 32 lead adjustments significant (for Drillisch the one-year beta against the FTSE All-World and the two-year beta against the FTSE All-Share).

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

[18] The London Stock Exchange closes at 5pm BST, while the markets in other countries may close earlier or later. Broad index data may therefore combine closing prices relating to different times of day. Timing adjustments therefore may be relevant for betas versus the FTSE All-World.

Table 14: UK MNOs, Dimson adjustments – up-to-date data

	1 Yr				2 Yr			
	Beta	Dimson Beta	Dimson SE	Significance	Beta	Dimson Beta	Dimson SE	Significance
Deutsche Telekom								
All World	0.86	0.74	0.14	Neither lag nor lead	0.81	0.82	0.10	Neither lag nor lead
All Share	0.83	0.91	0.13	Neither lag nor lead	0.77	0.87	0.08	Neither lag nor lead
All Europe	0.87	0.85	0.11	Neither lag nor lead	0.81	0.81	0.07	Neither lag nor lead
Orange								
All World	1.12	1.03	0.21	Neither lag nor lead	1.03	0.95	0.15	Neither lag nor lead
All Share	1.05	1.10	0.16	Only lead	0.95	0.96	0.11	Neither lag nor lead
All Europe	1.15	1.12	0.14	Neither lag nor lead	1.10	1.03	0.09	Neither lag nor lead
Telefonica								
All World	1.09	1.04	0.16	Neither lag nor lead	1.05	1.12	0.14	Neither lag nor lead
All Share	1.02	1.10	0.12	Neither lag nor lead	1.01	0.98	0.10	Neither lag nor lead
All Europe	1.13	1.08	0.12	Neither lag nor lead	1.19	1.17	0.09	Neither lag nor lead
Vodafone								
All World	0.76	0.66	0.18	Neither lag nor lead	0.70	0.78	0.11	Neither lag nor lead
All Share	0.90	0.87	0.15	Neither lag nor lead	0.73	0.76	0.09	Neither lag nor lead
All Europe	0.58	0.52	0.13	Neither lag nor lead	0.47	0.42	0.09	Neither lag nor lead
MNO Average								
All World	0.96	0.87			0.90	0.92		
All Share	0.95	1.00			0.86	0.89		
All Europe	0.93	0.89			0.89	0.86		

Note:
Betas are calculated using standard OLS.

III.A. TESTS FOR HETEROSCEDASTICITY AND AUTO-CORRELATION

We perform a series of diagnostic tests to assess if the equity 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 (differences in variance within sample) 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.

III.A.1.Heteroscedasticity

Figure 21 to Figure 24 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 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 21: Vodafone - residuals against fitted values

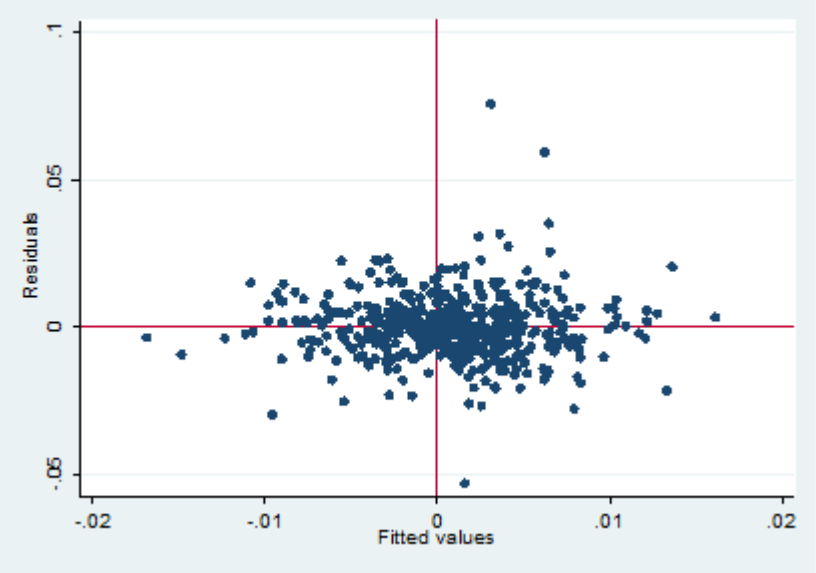


Figure 22: Deutsche Telekom - residuals against fitted values

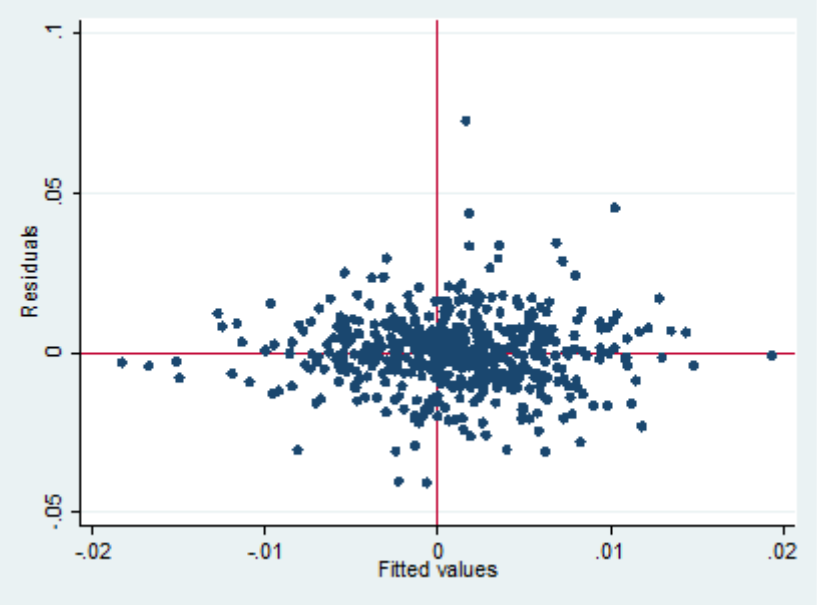


Figure 23: Orange - residuals against fitted values

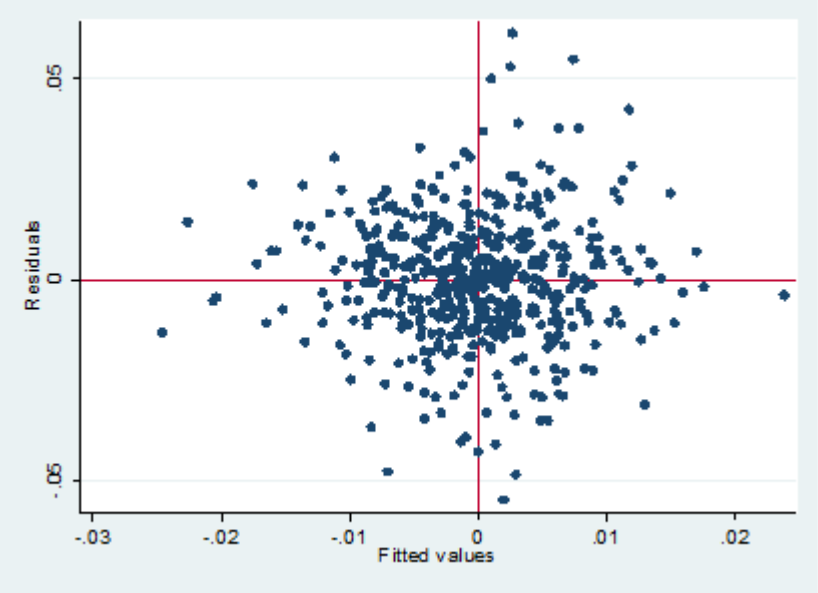
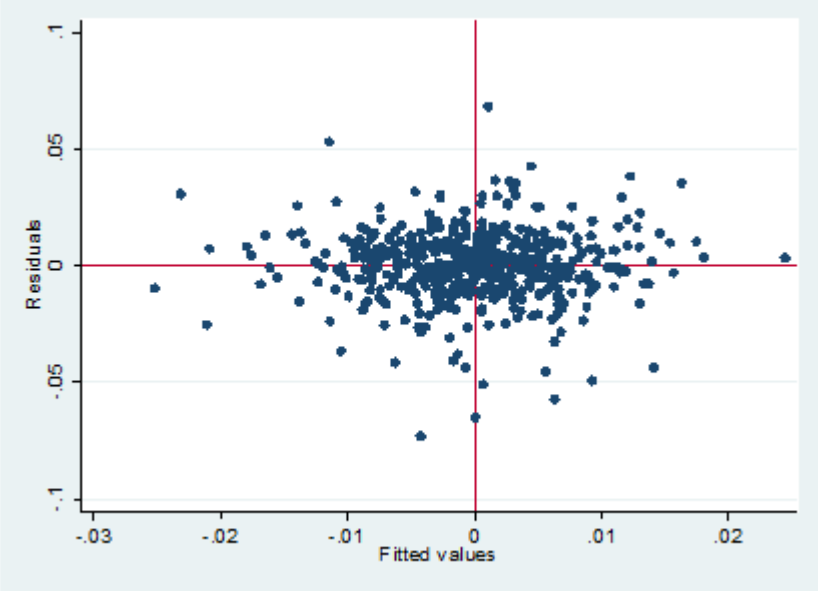


Figure 24: Telefonica - residuals against fitted values



We also examine whether there is change in the pattern of residuals over time. Figure 25 to Figure 28 do not show an apparent pattern of the residuals for the two-year estimation window. The plots again relate to two-year beta estimates calculated against the FTSE All-World.

Figure 25: Vodafone - residuals over time

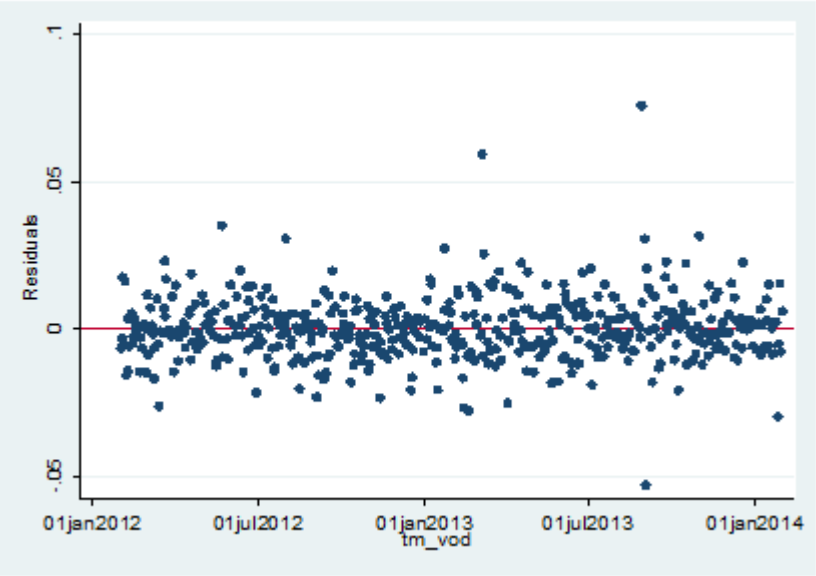


Figure 26: Deutsche Telekom - residuals over time

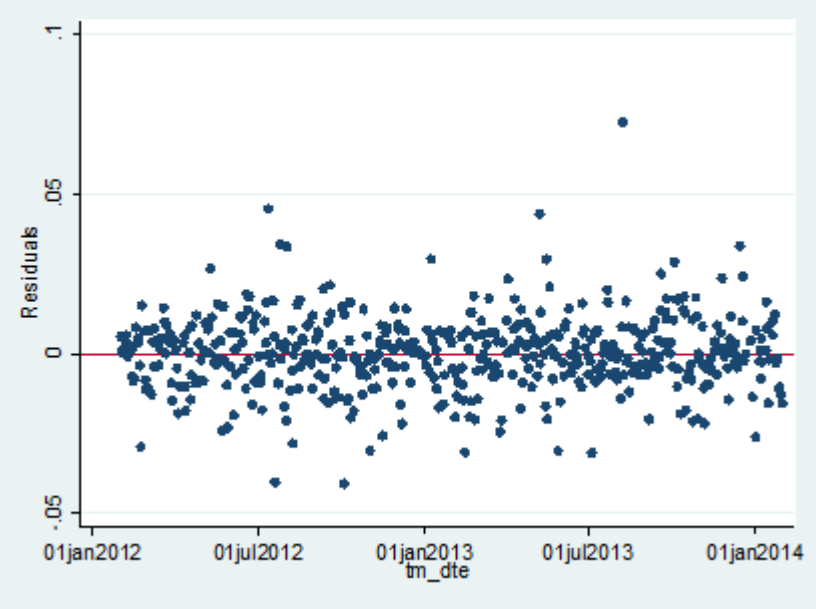


Figure 27: Orange - residuals over time

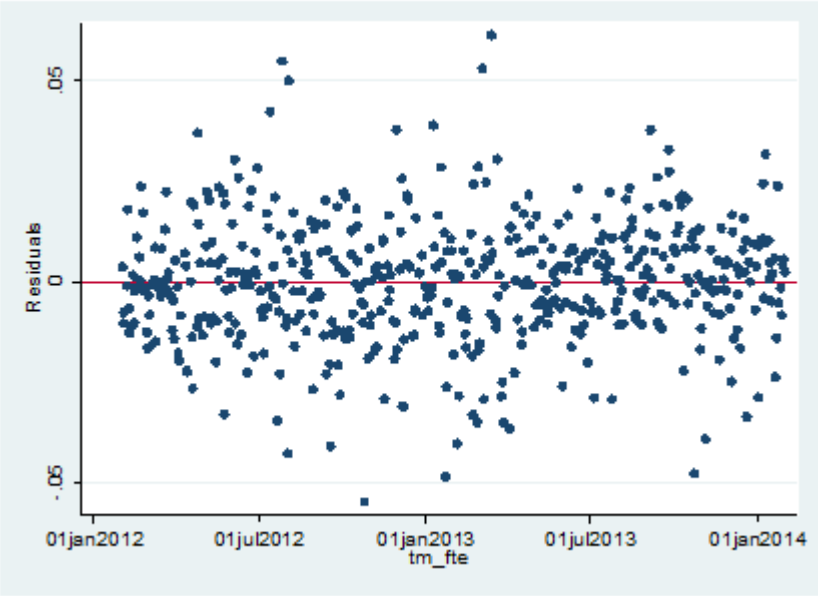
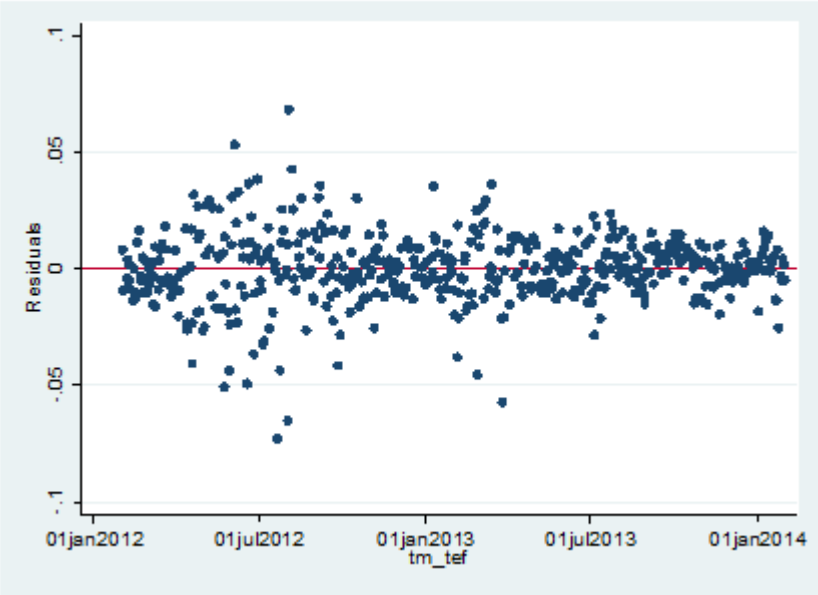


Figure 28: Telefonica - residuals over time



Even though simple inspection suggests that heteroscedasticity cannot be a major concern, we apply a formal test (White's test) to investigate further. Table 15 reports the results of the standard diagnostic test. It indicates the absence of heteroskedascity in all of the one- and two-year equity beta estimates apart from one: the two-year estimates for Telefonica against the FTSE All-Europe.

Table 15: White's test for heteroskedasticity – up-to-date data, UK MNOs

	1 yr			2 yr		
	White Stat	p-value	Heterosk-edascity	White Stat	p-value	Heterosk-edascity
Deutsche Telekom						
All World	0.80	0.67	No	2.29	0.32	No
All Share	0.64	0.73	No	1.21	0.54	No
All Europe	0.55	0.76	No	1.06	0.59	No
Orange						
All World	0.98	0.61	No	2.47	0.29	No
All Share	0.24	0.89	No	1.05	0.59	No
All Europe	0.64	0.73	No	0.21	0.90	No
Telefonica						
All World	2.02	0.36	No	0.58	0.75	No
All Share	0.21	0.90	No	1.26	0.53	No
All Europe	0.30	0.86	No	6.00	0.05	Yes
Vodafone						
All World	1.27	0.53	No	2.16	0.34	No
All Share	0.83	0.66	No	1.18	0.55	No
All Europe	0.29	0.87	No	0.40	0.82	No

III.A.2.Auto-correlation

We also perform a formal test for auto-correlation (the Durbin-Watson test). Perhaps unsurprisingly, this test indicates a degree of autocorrelation in all of the regressions. The effects of this auto-correlation are that standard errors will over-estimate the precision of the regression and that the OLS betas no longer represent the least variance estimator.

Table 16: Durbin–Watson test for autocorrelation – up-to-date data, UK MNOs

	1 yr		2 yr	
	DW Stat	Auto-Correlation	DW Stat	Auto-Correlation
Deutsche Telekom				
All World	1.52	Yes	1.57	Yes
All Share	1.45	Yes	1.51	Yes
All Europe	1.51	Yes	1.55	Yes
Orange				
All World	1.60	Yes	1.66	Yes
All Share	1.60	Yes	1.59	Yes
All Europe	1.62	Yes	1.60	Yes
Telefonica				
All World	1.50	Yes	1.57	Yes
All Share	1.49	Yes	1.50	Yes
All Europe	1.50	Yes	1.54	Yes
Vodafone				
All World	1.99	No	1.86	No
All Share	1.88	No	1.76	Indecisive
All Europe	1.89	No	1.78	No

III.A.3.Robust regression and Generalised Least Squares

We performed a robust regression that accommodates the presence of some heteroscedascity in the data. The robust regression is a standard feature of computerised statistical packages like STATA. The robust regression derives the same coefficients as standard OLS, but calculates standard errors robust to heteroscedascity. We find that the robust standard errors are close to the OLS ones (see Table 17). We also performed a fix for the presence of autocorrelation. In the presence of autocorrelation, the standard OLS and robust regression betas are unbiased, but they are no longer least variance estimators. We therefore performed a generalised least squares regression, which addresses the presence of autocorrelation in the residuals and results in an unbiased and least variance estimator.[19] The similarity in results provides confidence that neither heteroscedascity nor autocorrelation are significantly affecting our beta estimates.

[19] The GLS results are robust to heteroscedascity as well as autocorrelation.

Table 17: Robust and GLS equity betas and standard errors – up-to-date data, UK MNOs

	1 Yr					2 Yr				
	OLS Beta	SE	Robust SE	GLS Beta	GLS SE	OLS Beta	SE	Robust SE	GLS Beta	GLS SE
Deutsche Telekom										
All World	0.86	0.12	0.10	0.87	0.10	0.81	0.08	0.08	0.81	0.08
All Share	0.83	0.10	0.09	0.85	0.09	0.77	0.06	0.06	0.78	0.06
All Europe	0.87	0.09	0.08	0.87	0.08	0.81	0.05	0.05	0.81	0.05
Orange										
All World	1.12	0.15	0.13	1.12	0.13	1.03	0.11	0.10	1.03	0.10
All Share	1.05	0.12	0.12	1.05	0.12	0.95	0.08	0.08	0.96	0.08
All Europe	1.15	0.11	0.10	1.15	0.10	1.10	0.07	0.07	1.10	0.07
Telefonica										
All World	1.09	0.11	0.12	1.09	0.12	1.05	0.11	0.11	1.05	0.11
All Share	1.02	0.10	0.09	1.01	0.09	1.01	0.08	0.09	1.01	0.09
All Europe	1.13	0.08	0.07	1.12	0.08	1.19	0.06	0.07	1.19	0.07
Vodafone										
All World	0.76	0.11	0.10	0.77	0.10	0.70	0.07	0.07	0.70	0.07
All Share	0.90	0.10	0.09	0.89	0.09	0.73	0.06	0.06	0.73	0.06
All Europe	0.58	0.08	0.07	0.58	0.07	0.47	0.05	0.05	0.47	0.05
MNO Average										
All World	0.96			0.96		0.90			0.90	
All Share	0.95			0.95		0.86			0.87	
All Europe	0.93			0.93		0.89			0.89	

III.B. 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 standard 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 standard normal distributions except for the outliers: there are a few too many points a large number of standard deviations away from zero. Figure 29 to Figure 32 show histograms for two-year FTSE All-World regressions.

Figure 29: Studentized residuals - Vodafone

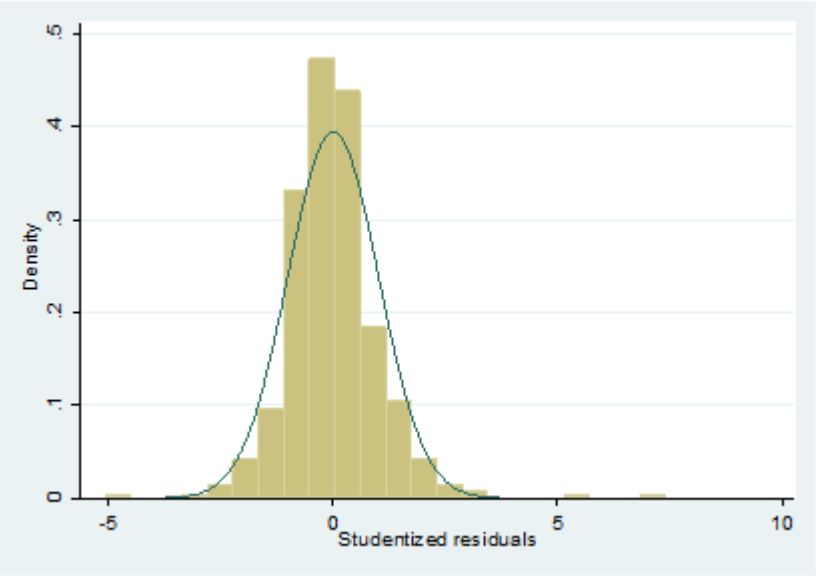


Figure 30: Studentized residuals – Deutsche Telekom

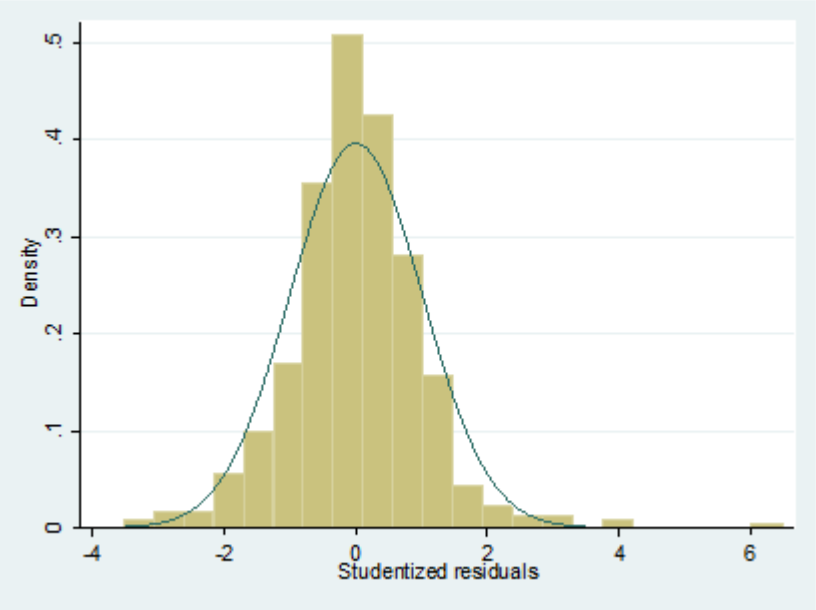


Figure 31: Studentized residuals – Orange

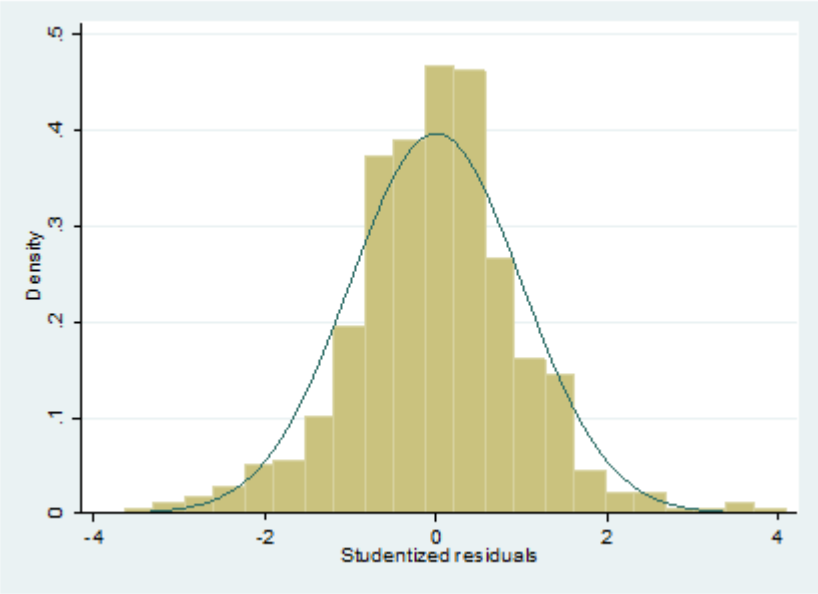
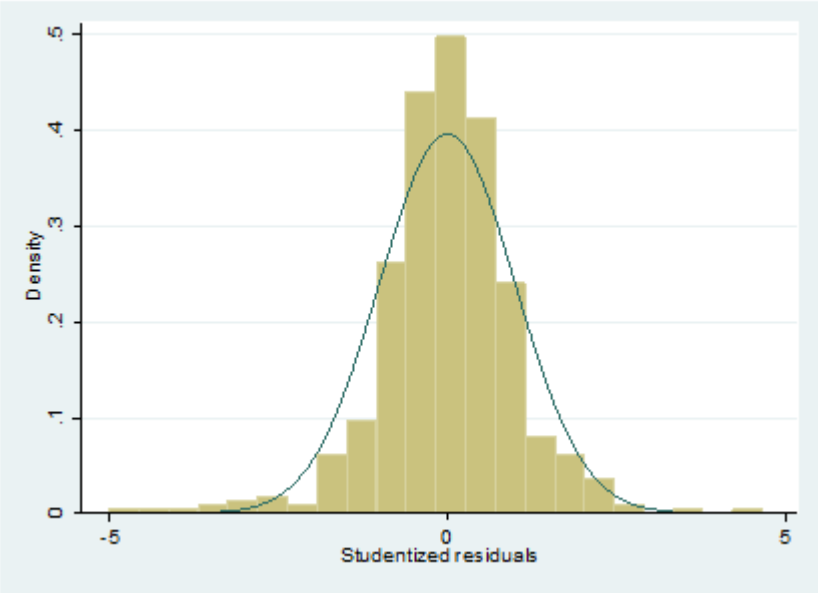


Figure 32: Studentized residuals – Telefonica



III.C. 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 thus having a large 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 18 to Table 21 list such

influential dates for the one and two-year betas calculated using up-to-date data for the four UK MNOs.

Table 18: Influential outliers

Vodafone					
All World		**All Share**		**All Europe**	
1 Yr	2 Yr	1 Yr	2 Yr	1 Yr	2 Yr
29-Aug-13	04-Jul-13	29-Aug-13	29-Aug-13	02-Sep-13	02-Sep-13
18-Apr-13	09-Mar-12	06-Mar-13	04-Jul-13	04-Jul-13	22-May-13
01-Nov-13	18-Apr-13	19-Feb-13	14-Sep-12	01-Nov-13	29-Jun-12
06-Mar-13	22-May-12	03-Sep-13	06-Mar-13	27-Jan-14	04-Jul-13
19-Feb-13	29-Aug-13	08-Mar-13	27-Jan-14	07-Feb-13	01-Nov-13
03-Apr-13	03-Sep-13	27-Jan-14	01-Nov-13	03-Apr-13	01-Aug-12
05-Jul-13	01-Jun-12	02-Sep-13	01-Aug-12	19-Sep-13	08-Mar-13
03-Sep-13	19-Feb-13	23-Apr-13	23-Jul-12	19-Feb-13	06-Mar-13
08-Mar-13	29-May-13	03-Apr-13	08-May-12	05-Jun-13	20-Mar-12
04-Jul-13	29-Jun-12	01-Nov-13	22-Mar-12	06-Mar-13	25-Jun-12
27-Jan-14	27-Jan-14		04-Sep-12	25-Mar-13	23-Apr-12
	02-Sep-13		02-Sep-13	22-May-13	24-Jan-13
	03-Feb-12		29-Jun-12	29-Aug-13	07-Feb-13
	01-Nov-13		03-Sep-13	03-Sep-13	25-Mar-13
	03-Apr-13		02-Apr-13		03-Sep-13
	08-Mar-13		01-Feb-12		19-Feb-13
	05-Jun-13		19-Feb-13		04-Sep-12
	06-Mar-13		20-Mar-12		14-Sep-12
	24-Jan-13		22-May-12		03-Apr-13
	25-Sep-13		23-Apr-13		29-Aug-13
	01-Aug-12		23-Apr-12		19-Sep-13
	25-Jun-12		03-Apr-13		27-Jan-14
	05-Jul-13		08-Mar-13		29-May-13
			24-Jan-13		22-May-12
					05-Jun-13

Table 19: Influential outliers

Deutsche Telekom					
All World		**All Share**		**All Europe**	
1 Yr	2 Yr	1 Yr	2 Yr	1 Yr	2 Yr
08-May-13	10-Oct-13	04-Oct-13	20-Jul-12	06-Jun-13	20-Jul-12
08-Aug-13	30-Jul-12	27-May-13	07-May-12	10-Oct-13	26-Jul-12
19-Dec-13	16-Dec-13	19-Dec-13	10-Oct-13	04-Apr-13	10-May-12
16-May-13	15-Feb-13	04-Apr-13	27-May-13	16-Dec-13	23-Feb-12
04-Oct-13	26-Jul-12	20-Sep-13	04-May-12	23-Apr-13	15-Feb-13
29-May-13	19-Dec-13	16-Dec-13	23-Feb-12	26-Nov-13	08-Feb-13
16-Dec-13	23-Jan-14	26-Nov-13	04-Jun-12	08-May-13	08-May-13
26-Mar-13	04-Oct-13	08-Feb-13	15-Feb-13	19-Dec-13	14-Sep-12
20-Sep-13	20-Sep-13	29-May-13	22-Jun-12	15-Feb-13	30-Jul-12
05-Jul-13	08-May-13	06-May-13	19-Dec-13	20-Jun-13	02-Nov-12
23-Jan-14	05-Jul-13	08-Aug-13	16-Dec-13	08-Aug-13	08-Aug-13
10-Oct-13	16-May-13	15-Feb-13	06-May-13	20-Sep-13	04-Oct-13
15-Feb-13	02-Nov-12	10-Oct-13	26-Nov-13	04-Oct-13	23-Apr-13
	04-Oct-12	26-Aug-13	08-Feb-13	08-Feb-13	22-Jun-12
	09-Jan-13	08-May-13	09-Jan-13	29-May-13	16-Dec-13
	20-Jul-12		03-Aug-12		26-Nov-13
	26-Mar-13		26-Jul-12		29-May-13
	18-May-12		13-Jul-12		09-Jan-13
	29-May-12		18-May-12		04-Oct-12
	13-Jul-12		26-Aug-13		29-May-12
	17-May-13		29-May-13		09-Aug-12
	06-Dec-12		04-Oct-13		20-Sep-13
	08-Aug-13		27-Aug-12		13-Jul-12
	29-May-13		04-Apr-13		04-Apr-13
	09-Aug-12		02-Nov-12		10-Oct-13
	03-Aug-12		20-Sep-13		03-Aug-12
			04-Oct-12		08-May-12
			08-Aug-13		19-Dec-13
			08-May-13		
			05-Jun-12		
			30-Jul-12		

Table 20: Influential outliers

Orange					
All World		**All Share**		**All Europe**	
1 Yr	2 Yr	1 Yr	2 Yr	1 Yr	2 Yr
23-Jan-14	04-Jun-12	08-Oct-13	20-Mar-12	05-Nov-13	22-Feb-12
05-Jul-13	03-Dec-13	06-May-13	07-May-12	10-Oct-13	20-Jul-12
08-Mar-13	03-Aug-12	26-Aug-13	25-Oct-12	21-Feb-13	08-Jun-12
04-Mar-13	29-Jun-12	14-Mar-13	02-Aug-12	04-Mar-13	01-Oct-12
26-Feb-13	05-Sep-13	05-Nov-13	10-Oct-13	04-Feb-13	04-Feb-13
10-Oct-13	09-Jan-13	10-Oct-13	03-Aug-12	14-Mar-13	08-May-12
03-Apr-13	04-May-12	04-Feb-13	06-May-13	03-Apr-13	06-Dec-12
14-Mar-13	26-Feb-13	27-May-13	04-Mar-13	04-Apr-13	05-Nov-13
27-Mar-13	14-Mar-13	04-Mar-13	12-Apr-12	06-Jun-13	14-Mar-13
05-Sep-13	08-Mar-13	03-Apr-13	27-Aug-12	23-Oct-13	22-Jan-13
23-Oct-13	27-Mar-13	05-Sep-13	20-Jul-12	05-Sep-13	05-Sep-13
20-Jun-13	23-Oct-13	05-Apr-13	27-May-13	20-Dec-13	22-Jun-12
03-Dec-13	10-Oct-13	23-Oct-13	23-Jan-14		03-Apr-13
	03-Apr-13	06-Feb-13	22-Jan-13		23-Oct-13
	22-Jan-13	03-Dec-13	05-Sep-13		04-Mar-13
	06-Dec-12	23-Jan-14	05-Apr-13		21-Feb-13
	29-Nov-12		14-Mar-13		18-Sep-12
	26-Jul-12		29-Jun-12		20-Dec-13
	13-Jul-12		13-Jul-12		02-Aug-12
	25-Oct-12		07-Jun-12		04-May-12
	23-Jan-14		08-Oct-13		20-Mar-12
	20-Jun-13		04-Jun-12		26-Jul-12
	01-Jun-12		09-Jan-13		29-Nov-12
	18-May-12		18-May-12		13-Jul-12
	04-Mar-13		23-Oct-13		25-Oct-12
			29-Nov-12		07-Jun-12
			22-Feb-12		09-Jan-13
			04-Feb-13		24-Apr-12
			22-Jun-12		10-Oct-13
			05-Jun-12		06-Jun-13
			04-May-12		03-Aug-12
			26-Aug-13		
			06-Feb-13		
			03-Apr-13		
			26-Jul-12		
			05-Nov-13		

Table 21: Influential outliers

Telefonica					
All World		**All Share**		**All Europe**	
1 Yr	2 Yr	1 Yr	2 Yr	1 Yr	2 Yr
14-Mar-13	02-Aug-12	09-Oct-13	29-May-12	23-May-13	01-Jun-12
05-Jul-13	04-Jun-12	27-May-13	09-Jan-13	04-Feb-13	29-May-12
26-Feb-13	04-Jul-13	14-Mar-13	26-Mar-13	14-Mar-13	12-Apr-12
04-Jul-13	29-Jun-12	25-Jul-13	04-Sep-12	08-Mar-13	04-Feb-13
25-Feb-13	06-Sep-12	26-Aug-13	05-Apr-13	25-Jul-13	03-Aug-12
15-Apr-13	26-Sep-12	08-Mar-13	23-May-12	26-Mar-13	19-Jun-12
26-Mar-13	06-Aug-12	06-May-13	06-Sep-12	01-Feb-13	24-Jan-14
24-Jan-14	08-Mar-13	06-Feb-13	18-Apr-12	04-Apr-13	04-Jun-12
20-Jun-13	18-Jun-12	26-Mar-13	26-Sep-12	09-Oct-13	18-Jun-12
08-Mar-13	26-Feb-13	26-Feb-13	12-Apr-12	24-Jan-14	23-May-13
04-Feb-13	04-May-12	24-Jan-14	18-May-12	27-Feb-13	26-Mar-13
	29-May-12	04-Jul-13	22-Jun-12	26-Feb-13	26-Feb-13
	03-Aug-12	04-Feb-13	26-Aug-13		06-Aug-12
	25-Jun-12	05-Apr-13	30-May-12		08-Jun-12
	24-Jul-12		24-Jan-14		04-Apr-12
	20-Jul-12		02-Aug-12		23-Jul-12
	26-Mar-13		27-May-13		29-Jun-12
	18-May-12		08-Jun-12		20-Jul-12
	23-May-12		14-Mar-13		18-Apr-12
	30-May-12		19-Jun-12		25-Jun-12
	01-Jun-12		27-Aug-12		02-Aug-12
	05-Jul-12		29-Jun-12		18-May-12
	24-Jan-14		07-Jun-12		26-Sep-12
			08-Mar-13		08-Mar-13
			07-May-12		22-Jun-12
			25-Jun-12		09-Jan-13
			06-May-13		04-Sep-12
			01-Jun-12		08-May-12
			04-May-12		04-May-12
			04-Jun-12		06-Sep-12
			05-Jun-12		14-Mar-13
			24-Jul-12		23-May-12
			03-Aug-12		07-Jun-12
			18-Jun-12		24-Jul-12
			06-Aug-12		
			05-Jul-12		

Table 22 compares the equity beta estimates obtained using standard OLS and GLS techniques with those obtained through the iterative regression giving less weight to outliers

and through a regression with all influential outliers removed. Figure 33 to Figure 36 then plot the rolling two-year estimates of the betas for the UK MNOs against the FTSE All-World. They compare the results of the standard OLS and GLS regressions, the weighted robust regressions and the regressions omitting all "outliers". The close similarity between the standard equity beta estimates and the other estimates provides confidence that outliers are not driving the shape of our results.

Table 22: The effect of influential outliers on equity betas– up-to-date data, UK MNOs

	1 yr					2 yr				
	Standard OLS	GLS	Robust	No Outliers	Number of Outliers	Standard OLS	GLS	Robust	No Outliers	Number of Outliers
Deutsche Telekom										
All World	0.86	0.87	0.85	0.81	13	0.81	0.81	0.75	0.80	26
All Share	0.83	0.85	0.83	0.80	15	0.77	0.78	0.72	0.73	31
All Europe	0.87	0.87	0.82	0.86	15	0.81	0.81	0.76	0.76	28
Orange										
All World	1.12	1.12	1.07	0.98	13	1.03	1.03	0.95	0.95	25
All Share	1.05	1.05	0.96	0.97	16	0.95	0.96	0.87	0.92	36
All Europe	1.15	1.15	1.04	1.03	12	1.10	1.10	1.02	1.02	31
Telefonica										
All World	1.09	1.09	1.12	1.06	11	1.05	1.05	1.07	1.06	23
All Share	1.02	1.01	0.99	0.95	14	1.01	1.01	0.96	0.97	37
All Europe	1.13	1.12	1.09	1.08	12	1.19	1.19	1.14	1.13	34
Vodafone										
All World	0.76	0.77	0.68	0.64	11	0.70	0.70	0.65	0.63	23
All Share	0.90	0.89	0.82	0.79	10	0.73	0.73	0.68	0.69	24
All Europe	0.58	0.58	0.56	0.54	14	0.47	0.47	0.45	0.46	25
MNO Average										
All World	0.96	0.96	0.93	0.87		0.90	0.90	0.86	0.86	
All Share	0.95	0.95	0.90	0.88		0.86	0.87	0.81	0.83	
All Europe	0.93	0.93	0.88	0.88		0.89	0.89	0.84	0.84	

Figure 33: Two-year equity beta against the FTSE-All World - Deutsche Telekom

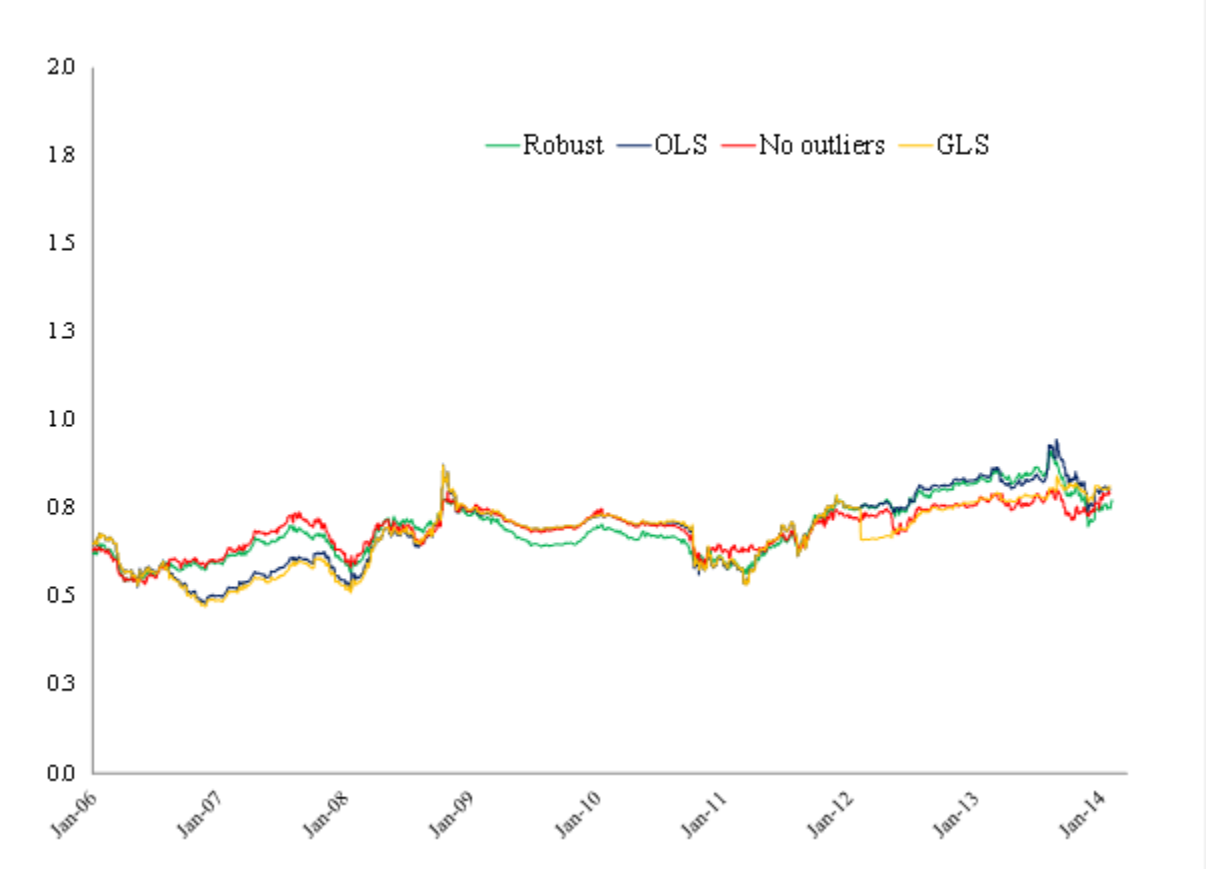


Figure 34: Two-year equity beta against the FTSE-All World - Orange

Figure 35: Two-year equity beta against the FTSE-All World - Telefonica

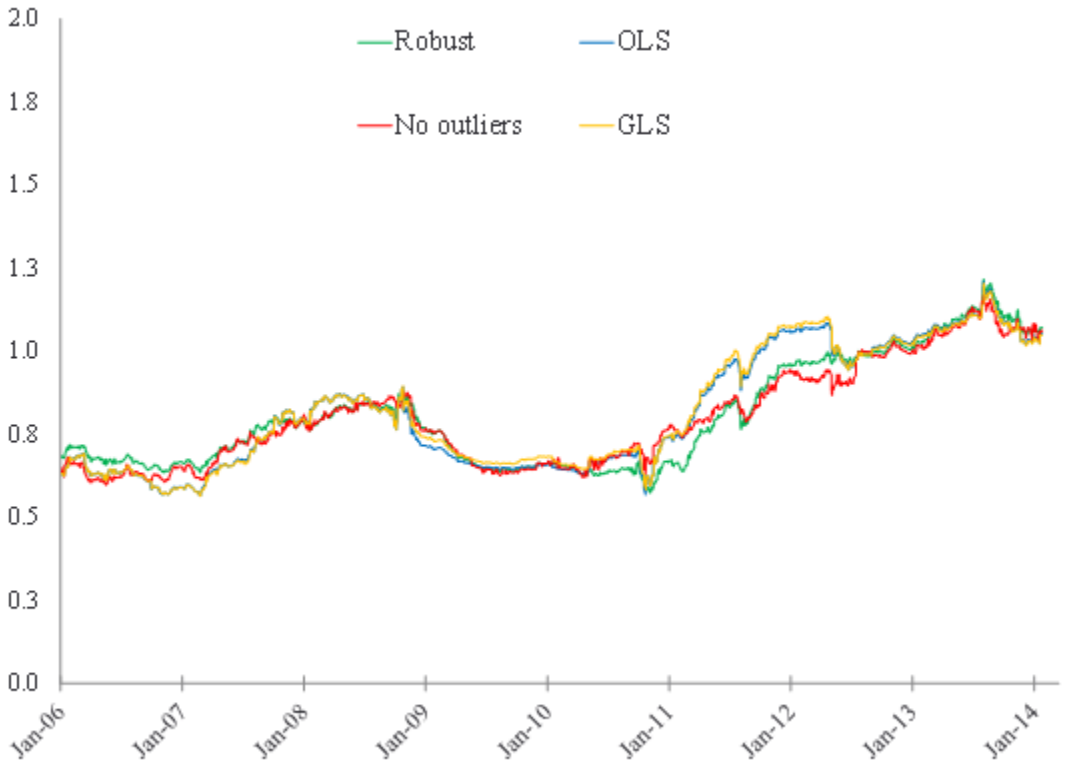


Figure 36: Two-year equity beta against the FTSE-All World - Vodafone

CAMBRIDGE
NEW YORK
SAN FRANCISCO
WASHINGTON
LONDON
MADRID
ROME

THE Brattle GROUP