NERA
ECONOMIC CONSULTING

Estimation of BT's Equity and Asset beta

For the Office of Communications (Ofcom)

19 May 2015

Project Team

Dr. Richard Hern

Dominik Huebler

Marija Spasovska

Arjun Dasgupta

Jinzi Guo

NERA Economic Consulting
Marble Arch House, 66 Seymour Street
London W1H 5BT
United Kingdom
Tel: 44 20 7659 8500 Fax: 44 20 7659 8501
www.nera.com

Contents

1. Introduction 1

2. Methodology 2
2.1. BT's Comparator Set 2
2.2. Data and Computation of Equity Betas 3
2.3. Statistical Analysis of Equity Betas 5
2.4. Computation of Asset Beta 7

3. Up-to-date Beta Estimates for BT and Comparators 9
3.1. BT and UK Utilities and Telcos 9
3.2. European Telcos 17
3.3. US Telcos 24

4. Further Analysis of BT's Asset Beta 30
4.1. BT's 1-year and 2-year OLS Asset Betas 30
4.2. BT 30-day Asset Beta 31
4.3. Kalman Filter 34

5. Conclusions 36

Appendix A. Statistical Tests 38
A.1. Visual Inspection of the data 38
A.2. Heteroscedasticity and Auto-correlation Tests 44
A.3. Outliers & Robust Regressions 47
A.4. Dimson Adjustment 48

Appendix B. Kalman Filter Technical Details 49
B.1. Context 49
B.2. The Kalman Filter Process 50

Appendix C. UK and European Telcos Revenue Breakdown 53

Appendix D. BT Revenue Breakdown 55

List of Tables

Table 3.1	BT and UK Telcos/Utilities Equity Beta against the FTSE All-Share and All-World indices	10
Table 3.2	BT and UK Telcos/Utilities Asset Beta against the FTSE All-Share and All-World indices	15
Table 3.3	EU Telcos Equity Beta against the FTSE All-Europe and FTSE All-World	18
Table 3.4	EU Telcos Asset Beta against the FTSE All-Europe and FTSE All-World	22
Table 3.5	US Telcos Equity Beta	25
Table 3.6	US Telcos Asset Beta against the S&P 500	28
Table A.1	UK Telcos/Utilities Heteroskedasticity Tests	45
Table A.2	UK Telcos/Utilities Autocorrelation Tests	46
Table A.3	UK Telcos/Utilities Outliers Tests	48
Table A.4	UK Telcos/Utilities Dimson Adjustment Tests	49
Table C.1	Breakdown of Revenue of BT Comparators	54
Table D.1	BT Segment Breakdown (%)	55

List of Figures

Figure 3.1	BT vs. UK Telcos / Utilities Average – 2Y Equity Beta against the FTSE All Share	11
Figure 3.2	BT and UK Telcos 2Y Rolling Equity Beta against FTSE All Share	12
Figure 3.3	BT and UK Utilities 2Y Rolling Equity Beta against FTSE All Share	12
Figure 3.4	BT and UK Telcos/Utilities Gearing Ratio	13
Figure 3.5	BT vs. UK Telcos / Utilities Average – 2Y Asset Beta against FTSE All Share	16
Figure 3.6	BT and UK Telcos 2Y Rolling Asset Beta against FTSE All Share	16
Figure 3.7	BT and UK Utilities 2Y Rolling Asset Beta against FTSE All Share	17
Figure 3.8	EU Telcos - 2Y Rolling Equity Beta	19
Figure 3.9	BT vs.EU Telcos Average – 2Y Equity Beta	20
Figure 3.10	EU Telcos Gearing Ratio	21
Figure 3.11	EU Telcos - 2Y Rolling Asset Beta	23
Figure 3.12	BT vs. EU Telcos Average – 2Y Asset Beta	23
Figure 3.13	Asset betas vs. Mobile Revenue shares for EU Comparators	24
Figure 3.14	US Telcos 2Y Rolling Equity Beta	26
Figure 3.15	US Telcos Gearing Ratios	27
Figure 3.16	US Telcos 2Y Rolling Asset Beta	29
Figure 4.1	BT Rolling 2Y Asset Beta against FTSE All Share	30
Figure 4.2	BT Rolling 30-day Asset Beta against FTSE All Share	31
Figure 4.3	BT Rolling 30D vs. Kalman Filtered Asset Beta against FTSE All Share	35
Figure 5.1	2Y Asset Beta Spectrum for BT and comparators	36
Figure A.1	BT	39
Figure A.2	National Grid	40
Figure A.3	Severn Trent	40
Figure A.4	Pennon	41
Figure A.5	United Utilities	41
Figure A.6	Centrica	42
Figure A.7	SSE	42
Figure A.8	TalkTalk	43
Figure A.9	Sky	43
Figure A.10	Colt	44
Figure B.1	Kalman Filter Process – First Iteration	52
Figure B.2	Kalman Filter - Process	52

1. Introduction

The Office of Communications (Ofcom), the UK Telecommunications Regulator, commissioned NERA Economic Consulting to review the approach to calculating equity and asset betas for BT and comparator companies undertaken by its previous consultants, the Brattle Group[1] and to update the equity and asset beta calculations for recent data.

This work is undertaken in the context of Ofcom's most recent Business Connectivity Market Review for the period 2016-19 (2016 BCMR) which covers the retail and wholesale markets for leased lines in the UK. Ofcom is required to undertake market reviews every three years, under the Communications Act 2003, implementing the EU regulatory framework for electronic communications. The process is designed to assess whether competitive pressures exist in the various segments of the market. If Ofcom does not find evidence of sufficient competitive constraints, it has the power to impose remedies such as ex ante regulation in the form of price controls.

We understand the equity and asset beta update set out in this report will be used as an input into Ofcom's broader assessment of BT's Weighted Average Cost of Capital (WACC), and more specifically as part of the 2016 BCMR.

The analysis in this report is set out as follows:

- Chapter 2 sets out our methodology for calculating the equity and asset beta for BT and the comparators;
- Chapter 3 reports up-to-date equity and asset beta estimates for BT and comparators;
- Chapter 4 assess BT's asset beta in more detail and discusses structural changes;
- Chapter 5 concludes the analysis, setting out the variant ranges of BT's asset beta and that of comparators.

The appendices to this report set out in greater detail (1) the statistical analysis carried out to assess the robustness of the equity beta results, and (2) other techniques (Kalman filtering) used in this report to cross-check the validity of the OLS estimates.

[1] The Brattle Group (3 March 2014): "Estimate of BT's Equity Beta". http://stakeholders.ofcom.org.uk/binaries/telecoms/ga/fixed-access-market-reviews-2014/draftstatement/15_annex15.pdf

2. Methodology

Ofcom's latest point of assessment of BT's WACC prior to this update was provided by Brattle (2014) [2] in support of the charge controls for local loop access and wholesale line rental services, at the last Fixed Access Market Review (FAMR).

In this section we assess the validity of Ofcom's existing methodology for calculating equity and asset betas, as implemented by its previous consultants the Brattle Group, and set out the methodology used in our update. Our approach is largely consistent with that of Brattle, with the exception of the calculation of gearing discussed in section 2.4 below; however, following discussions with Ofcom, we include an expanded set of beta sensitivities and cross-checks to confirm the robustness of the beta results, detailed below.

2.1. BT's Comparator Set

Within the CAPM framework, the equity beta estimate based on BT's traded stock price provides an indication of the riskiness of BT's *aggregate* cashflows, i.e. the risk of BT's integrated business model which in 2013 was comprised of the following segments: BT Global Services (31.7%), BT Business (15.8%), BT Consumer (18.1%), BT Wholesale (10.9%) and Openreach (22.8%).[3] The systematic risk will vary across BT's business segments to the extent that these differ in exposure to market, demand, regulatory and other systematic risks affecting investors' required return. BT's traded stock price therefore provides an indication of BT's aggregate systematic risk only.

For the purposes of assessing systematic risk within specific market segments (e.g. covered by the BCMR or FAMR) as characterized by the beta, Ofcom would preferably observe and assess "pure-play" companies that engage solely in that business activity, i.e. provision of access to the local loop for Openreach, retailing, content provision etc. However, since such pure-play comparators are not available as most telecommunications companies, including other former monopolies, engage in an integrated set of business activities, this assessment, in line with previous work, focuses on a specific, though somewhat expanded set of comparators for BT across the risk spectrum. These include:

- **UK Utilities,** including National Grid, Severn Trent, Pennon Group, United Utilities, Centrica and SSE;
- **UK Telecommunications companies,** including Talk Talk, Sky and Colt;
- **European former incumbent Telecommunications companies,** including Telefonica SA, Deutche Telecom, Belgacom SA, KPN, Orange SP, Telecom Italia SpA, Iliad SA, Mobistar, Telenor ASA, Tele2 AB and Swisscom AG; and
- **US Telecommunications companies,** including AT&T, Verizon, Time Warner Cable, Comcast and Century Link.

---

[2] Brattle's most recent report for the LLU WLR charge control can be found on Ofcom's website: http://stakeholders.ofcom.org.uk/binaries/telecoms/ga/fixed-access-market-reviews-2014/draftstatement/15_annex15.pdf

[3] Revenue breakdown percentage shown in brackets is from BT 2014 Annual Report.

We understand that Ofcom will use these comparator sets to inform its view on plausible disaggregation scenarios of BT's beta.

2.2. Data and Computation of Equity Betas

Data Sourcing and Frequency

We source stocks and index total returns and gearing data for each comparator listed above from Bloomberg, using 30 January 2015 as the cut-off date (unless expressly stated otherwise).

We use daily returns frequency taken on trading days[4], consistent with Brattle. The benefit of using daily (as opposed to less granular, i.e. weekly or monthly) data is that a greater number of data points are available for estimation, increasing the robustness of the regression results through lowering of the standard errors. However, the use of daily data is only appropriate in the case of liquid stocks which trade with similar frequency as the average market portfolio. Liquid stocks are not likely to suffer from asynchronous trading biases that arise if there is a difference between the speed with which new information is reflected in the share price of the stock in question relative to the speed with which new information is reflected in the stock market as a whole. Since both BT and the comparator sets are liquid[5], however, in this report we use beta estimates based on daily data.

Relevant Index

From an investor's perspective, the cost of capital should be estimated with reference to the financial market that best represents their investment opportunity set, as the cost of capital for any single investment is defined by the entire portfolio of investment opportunities to which an investor has access. This "set" is commonly referred to as the "market portfolio".

Consequently, a key consideration in the estimation of betas is whether to use a domestic stock market index, regional or worldwide index to proxy the market portfolio. In this report, consistent with Brattle, we report beta estimates against either local (or regional, in the case of the European comparator set) or global (All-world) indices. More specifically, we examine data for three market indices:

- the FTSE All-Share reflecting all stocks trading on the London Stock Exchange, used to estimate betas for UK comparators;
- the FTSE Europe reflecting stocks traded in Europe, used to estimate betas for European comparators; and
- the FTSE All-World reflecting a large proportion of publicly traded stocks around the world, used to cross-check the local/regional indices for UK and European comparators above; and

[4] Trading days include all days on which the stock exchange is open for trading, excluding weekends and public holidays.

[5] To test liquidity, we use the average bid-ask spread for each stock over a 2-year period and check whether that exceeds the threshold of 1%. All stocks considered in this sample are liquid.

- the S&P 500, a US stock index used to estimate betas for US comparators.

The appropriate reference market depends on the level of integration of individual capital markets. Greater market integration implies that investors face low transaction costs and barriers to international trade, allowing them to tap foreign capital markets. In this case, the relevant investment opportunity set is wider than the domestic market, and the equity and asset beta estimates should be based on a broad market index that captures the potential for diversification.

Despite wider global integration, however, the academic literature finds a general consensus that equity markets are less integrated than bond or money markets[6], and that there is "an equity home bias"[7], i.e. the observation that equity investors have a preference for domestic assets, despite the wider benefits of diversification. Such bias would suggest that systematic risk, as quantified by the asset beta parameter, is more appropriately captured by the stock correlations with a domestic market portfolio.

In this report, we report equity and asset betas against both a domestic and a wider market index; however, we note that UK regulators, including Ofcom, generally use domestic indices when setting price controls.[8]

Estimation Method - OLS vs. Kalman Filtering

Work on beta estimation carried out by Ofcom consultants has previously focused on estimating betas using the Ordinary Least Squares (OLS) regression technique. In this report, we use OLS analysis to estimate betas over 1-year and 2-year rolling windows.

The OLS technique is conceptually simple, widely-used and generally well understood in a regulatory context. The OLS technique attaches the same weight to each observation within a sample and estimates constant beta (slope) that defines the "line of best fit" between the explanatory variable (i.e. the equity benchmark returns) and the dependent variable (i.e. BT's stock returns). However, although OLS is a widely used and powerful technique, it is unable to capture structural changes in the beta quickly or as soon as they arise, unless the beta is calculated within a very short time-window. In fact, a wider estimation window (e.g. a 1-year window including c. 252 observations or a 2-year window including c. 504 observations) attaches a very small weight to new observations when these become part of such large samples. As such, rolling 1-year and 2-year OLS estimates reflect changes in the beta only very gradually, as the new information becomes a larger fraction of the sample.

---

6 See for e.g. Ogier, Tim et al (2004), The real cost of capital : a business field guide to better financial decisions.

7 See the seminal work of French, Kenneth; Poterba, James (1991). "Investor Diversification and International Equity Markets". American Economic Review 81 (2): 222–226 and Tesar, Linda; Werner, Ingrid (1995). "Home Bias and High Turnover". Journal of International Money and Finance 14 (4): 467–492.

8 As examples: the CMA in its Final Determination for Northern Ireland Electricity used the FTSE All Share Index as a proxy for the market portfolio when estimating equity beta for GB utility comparators. See Competition Commission (March 2014), Northern Ireland Electricity Limited Price Determination – A reference under Article 15 of the Electricity (Northern Ireland) Order 1992, Final determination, Appendix 13.3.Similarly, the most recent CAA Determination of the Cost of Capital for Q6 (2014-2019) used a local market index to estimate equity betas of international comparators. See the report from its Consultants, PWC (April 2013), Estimating the cost of capital in Q6 for Heathrow, Gatwick and Stansted, A report prepared for the Civil Aviation Authority (CAA), p.67.

Therefore, to cross-check the beta estimates and to assess potential structural changes in the data, as a first step we examine the short-term correlations (i.e. 30-day OLS betas). The 30-day OLS betas have the advantage that they are able to capture the short-term dynamics in investors' perception of risk. However, a disadvantage of using very short time-windows is that beta estimates will also pass through the short-term noise that are not structural, but rather transitory and purely due to market volatility.

As a second step, as a cross-check to the 1-year and 2-year OLS we therefore introduce an alternative technique, not used by Ofcom or its consultants in previous analysis - Kalman filtering, a Bayesian technique used in the context of estimating unobservable variables (in our case the "beta") that vary in time.[9] Unlike the OLS technique, Kalman has the advantage that it can capture the short-term changes in the beta, whilst distinguishing between persistence and noise in the beta signals. Kalman is therefore able to pick-up structural changes in the beta much more quickly than a long-term OLS, and with less volatility than the short-term OLS under certain conditions. We apply the Kalman filtering technique to estimate time-varying beta for BT in section 4 of this report. We discuss the technique in more detail in Appendix B.

2.3. Statistical Analysis of Equity Betas

Statistical Testing of CAPM Assumptions

The Ordinary Least Squares (OLS) method is generally the most widely used method for estimating CAPM betas, under the Classical Normal Linear Regression Model (CNLRM). However, this method is based on a set of assumptions, which when violated, results in biased[10] and/or inefficient[11] (i.e. not minimum variance) beta estimates. We test the following key assumptions[12]:

1) *The error terms of the regression are normally distributed around a zero mean value;*
2) *The error terms are homoskedastic,* i.e. the error terms have constant variance across the sample; and
3) *The error terms are not autocorrelated*, i.e. there is no systematic dependence across the error terms.

---

9 Kalman, R. (1960), "A new approach to linear filtering and prediction problems", *Journal of Basic Engineering*, 82: 34–45. For an accessible introduction of the technique, see Arnold T. et al (2008), "A simplified approach to understanding the Kalman Filter Technique", *The Engineering Economist, 53: 14-155.* Also see Berardi A. et al. (2002), *Estimating Value at Risk with the Kalman Filter,* Dipartimento Studi Finanziari, Università di Verona.

10 In statistics, an unbiased estimate refers to the property that the sample statistic converges to its true "population" value in repeated samples.

11 In statistics, an efficient estimate is an estimate/sample statistic that has the minimum variance, i.e. lowest uncertainty surrounding that estimate/sample statistic.

12 See standard textbook on Damodar N. Gujarati and Dawn C. Porter: *Basic Economics*, Chapter 3 and 4. The model also includes the following assumptions: (1) the model is linear in the parameters (2) the errors and the independent variable (in this case the market return) are independent, i.e. have zero covariance; and (3) the number of observations is greater than the number of parameters to be estimated within the model.

Failure of the normality assumption above can bias the beta estimates, and may require alternative methods of estimation which can capture non-normality (e.g. the Third-moment CAPM method). On the other hand, the presence of autocorrelation and /or heteroskedasticity does not bias the beta estimates, but affects the confidence intervals (and therefore statistical inferences) around those estimates.

We carry out standard statistical tests (see Appendix A for more detail) to assess whether the statistical assumptions above are satisfied within the respective comparator samples. In the presence of heteroskedasticity and/or autocorrelation, we report estimates based on the Generalized Least Squares (GLS) method, an alternative estimation method to the standard OLS which can address both of these issues[13].

Outliers

We also test for "outliers", i.e. influential observations in the data, the removal of which can significantly affect the beta estimates. Excluding abnormal periods of the data is equivalent to assuming they will not occur in the future. In this instance, to assess the potential impact from outliers, consistent with the previous approach taken by Brattle we (1) conduct regressions excluding the outliers, as well as (2) robust regressions which apply alternative weighting to the observations in the sample giving less weight to observations that have strong influence on the regression output (as measured by the residual), and are therefore less sensitive to outliers. We do not observe large differences between these estimates (see appendix A.3) due to which we continue to use OLS or GLS estimates as appropriate.

Dimson Adjustment for Asynchronious Trading

Beta estimates based on daily data can be subject to estimation bias. A common problem cited in the academic literature is that when stocks are traded more thinly or thickly than the market average, price signals are not assimilated simultaneously. Consequently, the firm's share price may react more slowly/quickly than the market price, and as a result a lead or a lag term of the market price can have a significant correlation with the stock price.

Dimson (1979)[14] developed a procedure for correcting such bias in the beta estimates, via the estimation of an auxiliary regression that includes (typically symmetric) lag and lead coefficients of the market return. The adjusted beta is then calculated as the sum of the coefficients of this multiple regression. Consistent with Brattle, our implementation includes a single lead and a lag coefficient, taking the following form:

$$R_{s,t} = \alpha + \beta^{t-1} M_{t-1} + \beta^{t} M_t + \beta^{t+1} M_{t+1} + \varepsilon_t \qquad (1)$$

Where:

M_t is the reference market return in time *t*;

[13] See standard textbook on Damodar N. Gujarati and Dawn C. Porter: *Basic Economics*, Chapter 11.

[14] Dimson, Elroy 1979, "Risk Measurement When Shares are Subject to Infrequent Trading," Journal of Financial Economics 7, June, pp. 197-226.

$R_{s,t}$ is the return of stock s in time *t*;

α is a constant term; and

ε_t is the error term in time *t*, which is distributed as N(0, σ^2).

When markets are efficient and the stock in question trades as often as the market portfolio, then all public information is assimilated in the stock and market prices contemporaneously. In this situation, the lag and the lead term in equation (1) are not statistically significantly different from zero, and only the contemporaneous market return is correlated with the market price. In the presence of non-synchronous trading, the coefficients on the lag/lead market returns can be statistically significantly different from zero.

Dimson (1979) showed that an estimate of the true beta coefficient of a stock in the presence of the effect described above is obtained by the sum of the beta coefficients in equation (1):

$$\beta^{Dimson} = \sum_{k=t-1}^{k=t+1} \beta^k \quad (2)$$

We discuss the results of this analysis in more detail in appendix A.4. We find that none of the comparators have statistically jointly significant lead and lag terms, which is consistent with our finding that the stocks in our sample are liquid and therefore unlikely to be affected by asynchronous trading bias. Only BT is found to be significantly correlated with one-day proceeding price of FTSE All World, but the lead and the lag are not jointly significant.

2.4. Computation of Asset Beta

Asset beta formula

Equity betas are affected not only by the underlying structural, systematic risk of the business but also by financial risk, which depends on the level of debt obligations incurred by the business. We de-lever equity betas to control for the embedded financial risk element and arrive at asset beta estimates that are comparable across companies with different capital structures. To de-lever the equity betas we use the standard Miller formula, consistent with Brattle.[15]

Gearing

We calculate gearing, defined as the total (gross) value of debt to assets, based on data provided by Bloomberg[16]. This is a departure from Brattle's approach, which used a working capital screen, including long-term debt only if working capital of the company was positive, and both long and short-term debt (i.e. gross debt) if the working capital of the company was negative. We note that in practice, the debt and gearing estimates for BT are not affected by

[15] $\beta a = \frac{E}{D+E}\beta e + \frac{D}{D+E}\beta d$, where βa is the asset beta of the company, βe is the equity beta and βd is the debt beta of the company, and E and D are the values of equity and debt respectively.

[16] Bloomberg provides gearing data based on the book value of debt and the market value of equity. Debt also includes finance leases. Cash is not netted off.

removing the working capital screen because BT's working capital has been negative for an extended period.

Brattle's working capital screen effectively assumes that short-term cash would be used to cover short-term liabilities. However, the alternative view is that companies need their cash holdings to finance their ongoing activities. Since we have no evidence that short term cash held by all these operators would be used to cover short term liabilities, we use total value of debt (i.e. gross debt) as a gearing assumption in the asset beta calculations in this report.

Debt beta

In this report we also conduct a sensitivity check on asset beta by assuming a debt beta of both 0 and 0.1, consistent with Brattle. While other regulators have often assumed a debt beta of 0 (on grounds that debt of regulated utilities is relatively low-risk) Ofcom has previously used a debt beta in the range from 0.1 to 0.15, with the most recent 2014 FAMR decision using a debt beta of 0.1. [17] In this report asset betas values quoted are calculated using a debt beta of 0.1 unless stated otherwise.

The Competition and Markets Authority (previously the Competition Commission) has backed up the view that debt betas are non-zero for utility debt as well, including in the following determinations:

- Competition Commission (2010), Bristol Water used a debt beta range of 0 and 0.1;[18]
- Competition Commission (2007), A report on the economic regulation of the London airports companies (Heathrow Airport Ltd and Gatwick Airport Ltd) used a debt beta of 0.1, from an estimated range of 0.09 – 0.19.[19]

[17] Ofcom (2014): Fixed access market reviews: wholesale local access, wholesale fixed analogue exchange lines, ISDN2 and ISDN30 – Annexes, Annex 14: Cost of Capital, p.185, para A14.124

[18] See para 117. http://webarchive.nationalarchives.gov.uk/20140402141250/http://www.competition-commission.org.uk/assets/competitioncommission/docs/pdf/non-inquiry/rep_pub/reports/2010/fulltext/558_appendices.pdf

[19] See Appendix F, para 105-106 accessed here: http://www.caa.co.uk/docs/5/ergdocs/ccreport_appf.pdf

3. Up-to-date Beta Estimates for BT and Comparators

In this section we report up-to-date beta estimates for BT and BT's three reference sample groups, i.e. (1) UK telcos and utilities, (2) European telcos and (3) US telcos. In the following sub-sections, we set out equity betas, gearing ratio and asset betas for the three reference samples respectively. All of the estimates reflect data up to 30 January 2015.

3.1. BT and UK Utilities and Telcos

3.1.1. Equity beta estimation

Table 3.1 reports equity beta estimates for BT and UK comparators against both the FTSE All Share and FTSE All World index.

We estimate BT's up-to-date 2-year equity beta of 0.97 against FTSE All Share, and 0.83 against FTSE All World. Our estimate is slightly lower than the BT equity beta of 1.01 against the FTSE All-Share published by Ofcom in the June 2014 FAMR decision.[20]

The average 2-year equity beta for UK utilities against the FTSE All Share is 0.63, while the average equity beta for UK Telcos (excluding BT) is 0.71. We estimate slightly lower average 2-year equity beta of 0.56 for UK utilities against the FTSE All World, perhaps reflecting greater diversification of this index, although the 2-year equity beta for UK telcos against the FTSE All World is slightly higher at 0.72. [21]

[20] Ofcom (2014): Fixed access market reviews: wholesale local access, wholesale fixed analogue exchange lines, ISDN2 and ISDN30 – Annexes, Annex 14: Cost of Capital, p.163.

[21] In the presence of heteroskedasticity and autocorrelation in some of the beta regressions for this sample of comparators, we report GLS beta instead of OLS.

Table 3.1
BT and UK Telcos/Utilities Equity Beta against the FTSE All-Share and All-World indices

		FTSE All-Share		FTSE All-World	
		OLS / GLS*		OLS / GLS*	
		Beta	SE	Beta	SE
BT					
	1Y	0.85	0.08	0.73	0.12
	2Y*	0.97	0.07	0.82	0.09
National Grid					
	1Y	0.71	0.06	0.69	0.08
	2Y*	0.69	0.04	0.60	0.06
Severn Trent					
	1Y*	0.76	0.07	0.69	0.10
	2Y	0.67	0.07	0.61	0.09
Pennon Group					
	1Y	0.55	0.07	0.45	0.10
	2Y	0.53	0.05	0.49	0.07
United Utilities					
	1Y*	0.73	0.08	0.68	0.11
	2Y*	0.63	0.06	0.57	0.07
Centrica					
	1Y	0.82	0.08	0.81	0.11
	2Y	0.67	0.06	0.55	0.08
SSE					
	1Y	0.59	0.08	0.54	0.11
	2Y	0.60	0.06	0.51	0.07
TalkTalk					
	1Y	0.67	0.12	0.72	0.15
	2Y	0.75	0.10	0.78	0.12
Sky					
	1Y*	0.72	0.08	0.69	0.12
	2Y*	0.64	0.07	0.65	0.09
Colt					
	1Y*	0.74	0.15	0.77	0.19
	2Y*	0.75	0.10	0.72	0.13
Utilities Average					
	1Y	0.69		0.64	
	2Y	0.63		0.56	
Telcos Average					
	1Y	0.71		0.73	
	2Y	0.71		0.72	

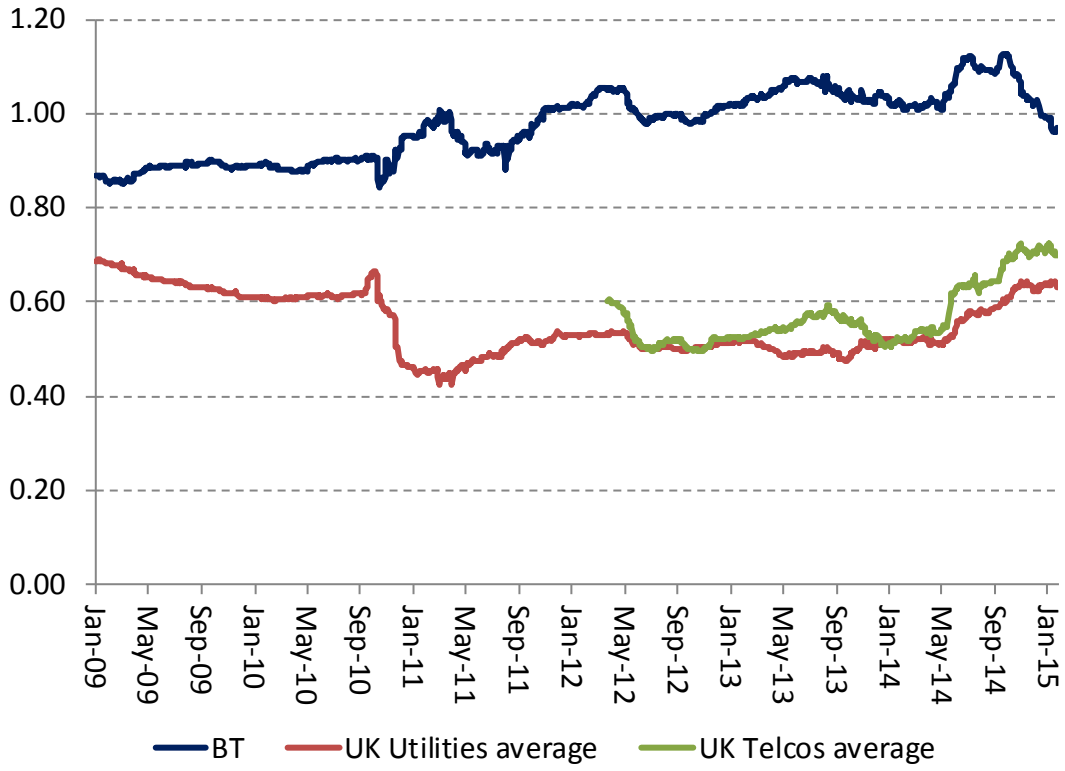
*GLS Reported where regression diagnostics show heteroskedasticity or autocorrelation.
Source: NERA Calculation

Figure 3.1 to Figure 3.3 illustrate the time series of the 2-year equity betas for BT and UK comparators against the FTSE All Share over the period January 2009 – January 2015.

For BT, this analysis shows that the 2-year equity beta has increased from 2009 to late 2014 before decreasing at the end of 2014 / start of 2015.

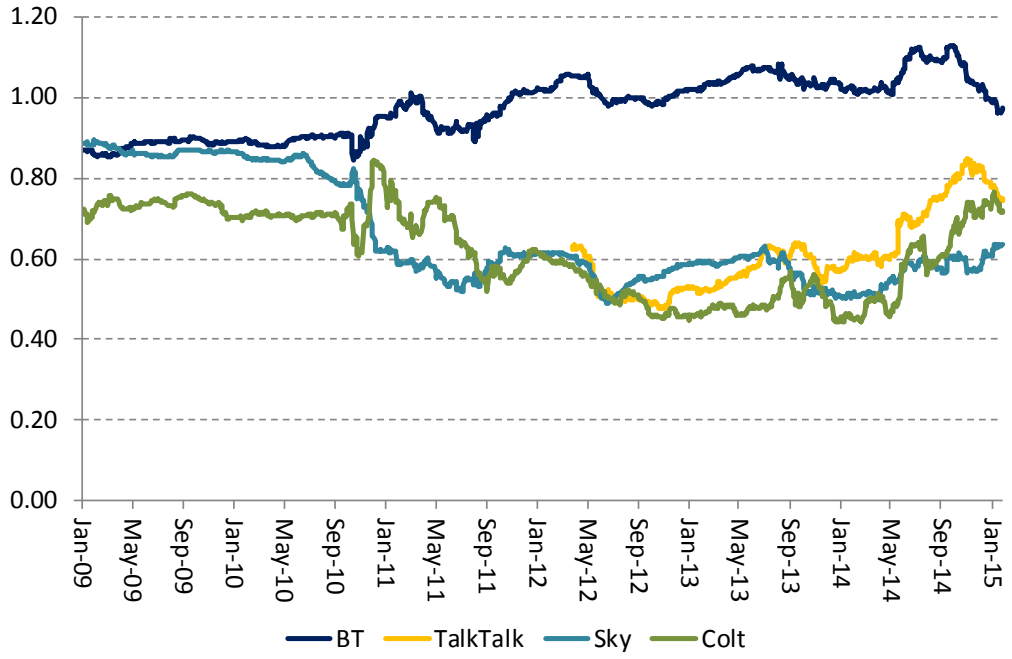
For the other comparator companies, however, the trend is markedly different. It shows that the equity betas for UK utilities / telcos (excluding BT) have generally decreased from 2009 to 2013 and then increased in 2014.

Figure 3.1
BT vs. UK Telcos / Utilities Average – 2Y Equity Beta against the FTSE All Share



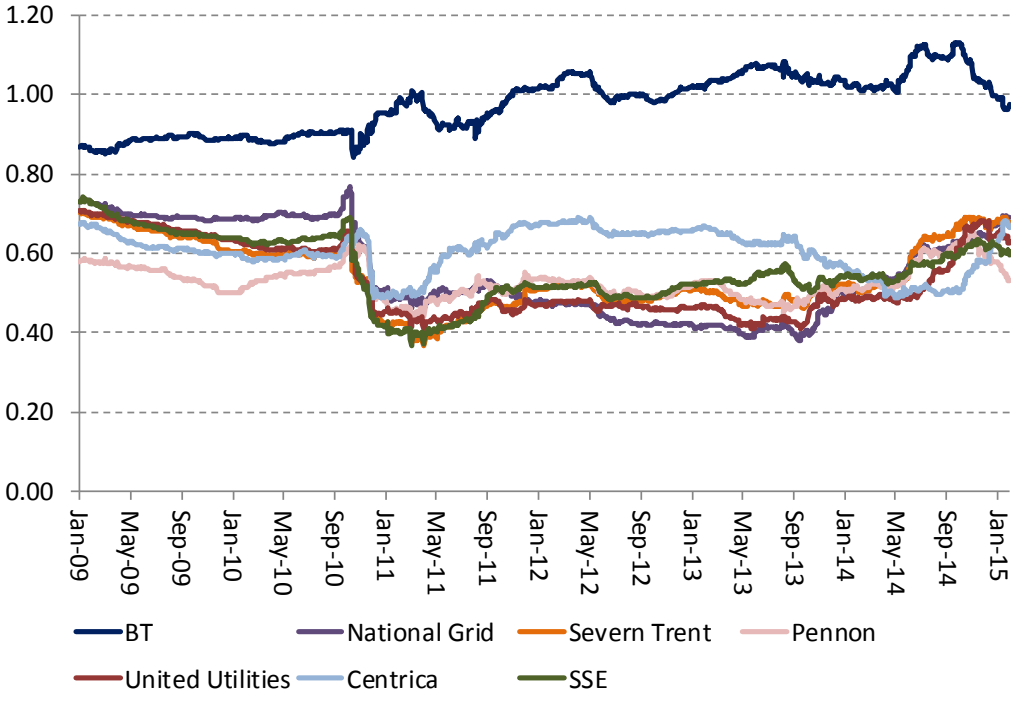
Note: UK Telcos 2-year average data goes back to March 2012 as TalkTalk was listed on March 2010.
Source: NERA Analysis of Bloomberg data

Figure 3.2
BT and UK Telcos 2Y Rolling Equity Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

Figure 3.3
BT and UK Utilities 2Y Rolling Equity Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

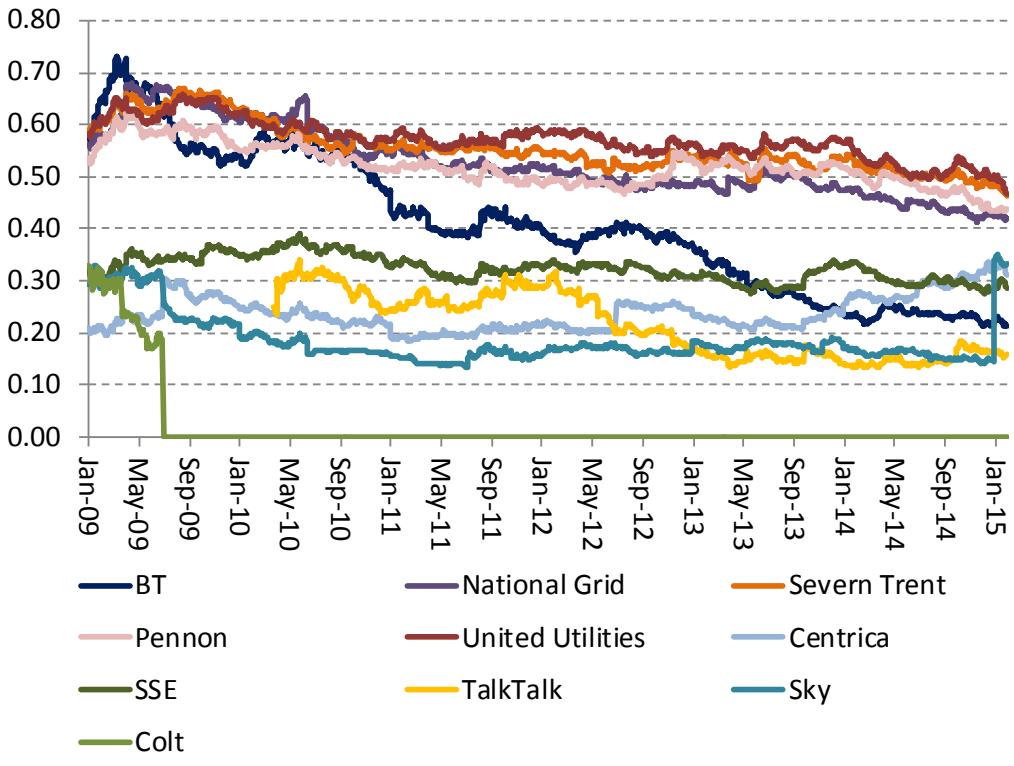
3.1.2. Gearing and asset beta

Equity betas are affected not only by the underlying structural, systematic risk of the business but also by financial risk, which depends on the level of debt obligations incurred by the business. We de-lever equity betas to control for the embedded financial risk element and arrive at asset beta estimates that are comparable across companies with different capital structures. For BT and each of the comparator companies we calculate asset betas based on the Miller formula as described above in section 2.4

BT's gearing was 21.3% on 30 January 2015, having exhibited a steady decline over most of the period since 2009, as shown in Figure 3.4.

Figure 3.4 also shows the evolution of the gearing ratios for the UK comparators' from January 2009 to January 2015. Most comparators had declining gearing ratios over the period since 2009, which somewhat stabilized around 2014. The exceptions to this are Centrica, whose gearing rose by c.10 percent, [22] and Sky, which experienced a sharp rise in gearing from 15% to 34% at the end of 2014.[23]

Figure 3.4
BT and UK Telcos/Utilities Gearing Ratio



Source: NERA Analysis of Bloomberg data

[22] Centrica's gearing ratio has been increasing since mid-year 2013 due to the continuous decline in stock price.

[23] Sky issued £5bn of bonds to fund Sky Deutschland and Sky Italia acquisition.

We use the average gearing ratios estimated over the same estimation window as the equity betas to de-lever the equity betas.

Table 3.2 and the accompanying figures 3.5 – 3.7 below report asset betas for BT and UK telcos and utilities. Our asset beta estimates, based on a debt beta of 0.1 are as follows:

- BT's 2-year asset beta stands at 0.74 against FTSE All Share and 0.64 against the FTSE All World.
- UK utilities have an average 2-year asset beta of 0.40 against the FTSE All Share and 0.36 against the FTSE All World; and
- UK telcos have an average 2-year asset beta of 0.65 against both FTSE All Share and the FTSE All-World.

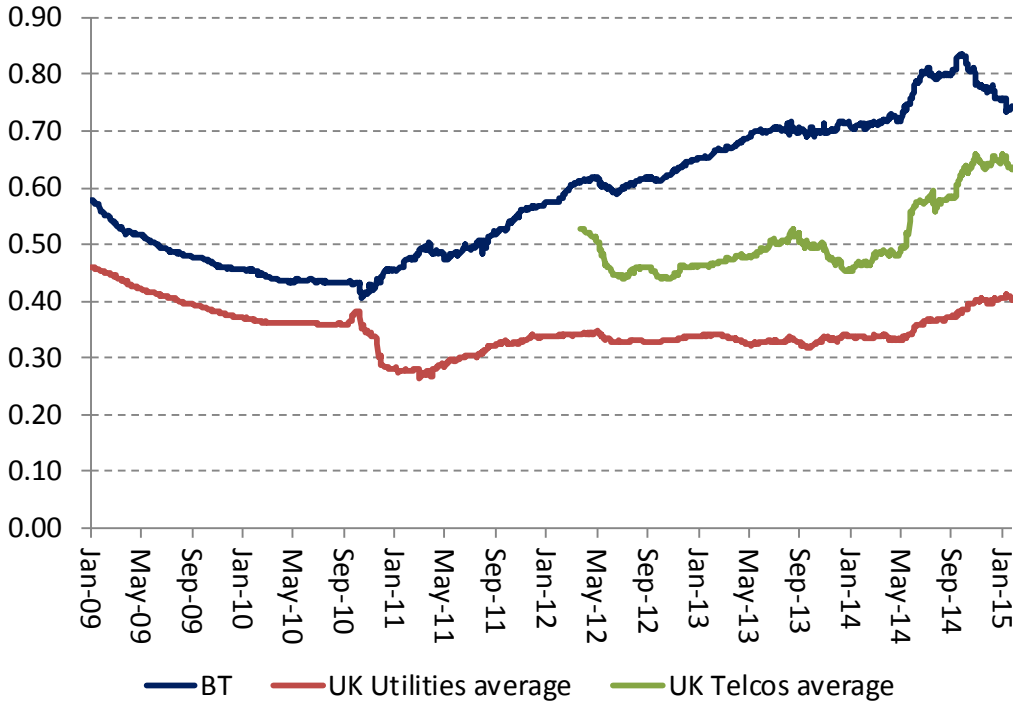
UK comparator asset betas show a mild upward trend in 2014 but are stagnant more recently or somewhat decreasing. BT's asset beta has risen significantly more than the asset beta for comparators over 2014, but has recently decreased, as shown in Figure 3.5.

Table 3.2
BT and UK Telcos/Utilities Asset Beta against the FTSE All-Share and All-World indices

			FTSE All-Share		FTSE All-World	
		Gearing	Beta debt = 0 OLS/GLS	Beta debt = 0.1 OLS/GLS	Beta debt = 0 OLS/GLS	Beta debt = 0.1 OLS/GLS
BT						
	1Y	0.23	0.65	0.67	0.56	0.58
	2Y	0.26	0.71	0.74	0.61	0.64
National Grid						
	1Y	0.44	0.40	0.44	0.38	0.42
	2Y	0.47	0.37	0.41	0.32	0.37
Severn Trent						
	1Y	0.50	0.38	0.43	0.35	0.40
	2Y	0.52	0.33	0.38	0.30	0.35
Pennon Group						
	1Y	0.48	0.29	0.33	0.23	0.28
	2Y	0.50	0.26	0.31	0.25	0.30
United Utilities						
	1Y	0.52	0.35	0.40	0.33	0.38
	2Y	0.54	0.29	0.34	0.26	0.32
Centrica						
	1Y	0.29	0.58	0.61	0.57	0.60
	2Y	0.26	0.49	0.52	0.41	0.43
SSE						
	1Y	0.30	0.41	0.44	0.38	0.41
	2Y	0.30	0.42	0.45	0.35	0.38
TalkTalk						
	1Y	0.15	0.56	0.58	0.61	0.63
	2Y	0.15	0.63	0.65	0.66	0.67
Sky						
	1Y	0.18	0.59	0.61	0.57	0.58
	2Y	0.18	0.53	0.55	0.54	0.56
Colt						
	1Y	0.00	0.74	0.74	0.77	0.77
	2Y	0.00	0.75	0.75	0.72	0.72
Utilities Average						
	1Y	0.42	0.40	0.44	0.37	0.42
	2Y	0.43	0.36	0.40	0.31	0.36
Telcos Average						
	1Y	0.11	0.63	0.64	0.65	0.66
	2Y	0.11	0.64	0.65	0.64	0.65

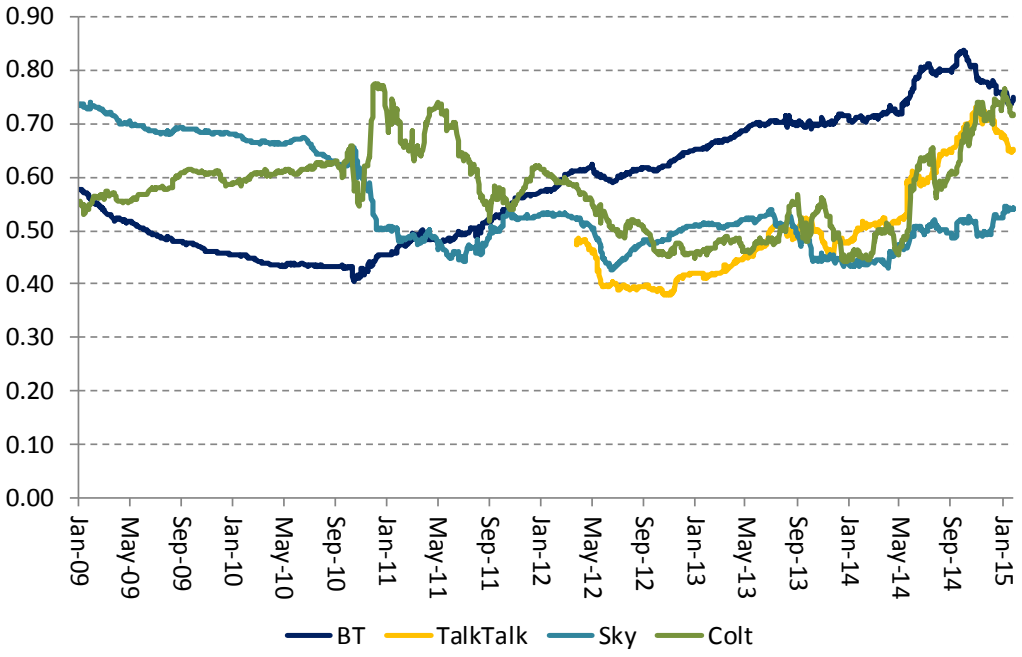
*GLS Reported where regression diagnostics show heteroskedasticity or autocorrelation.
Source: NERA Calculation

Figure 3.5
BT vs. UK Telcos / Utilities Average – 2Y Asset Beta against FTSE All Share



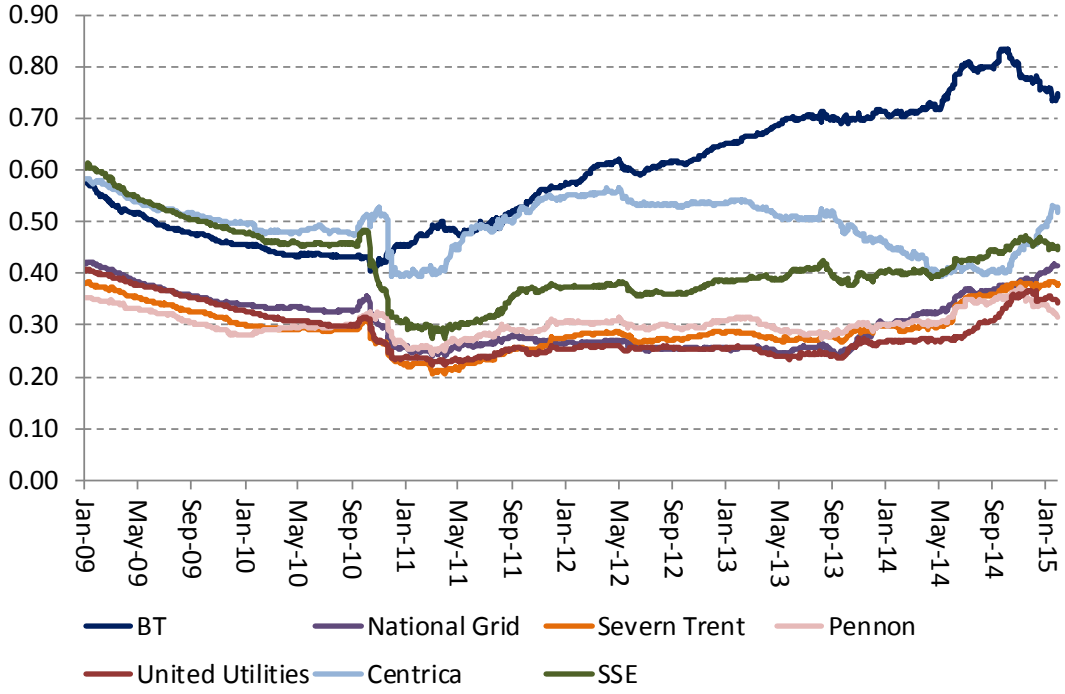
Source: NERA Analysis of Bloomberg data

Figure 3.6
BT and UK Telcos 2Y Rolling Asset Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

Figure 3.7
BT and UK Utilities 2Y Rolling Asset Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

3.2. European Telcos

The European telcos reference sample includes eleven telecommunication companies, all former incumbents in their local market.

3.2.1. Equity beta estimation

In Table 3.3 we report European telcos beta estimates against both the FTSE All Europe index and FTSE All World indices. The average equity beta for the European comparators sample is 0.74 against the FTSE All Europe and 0.98 against the FTSE All World.

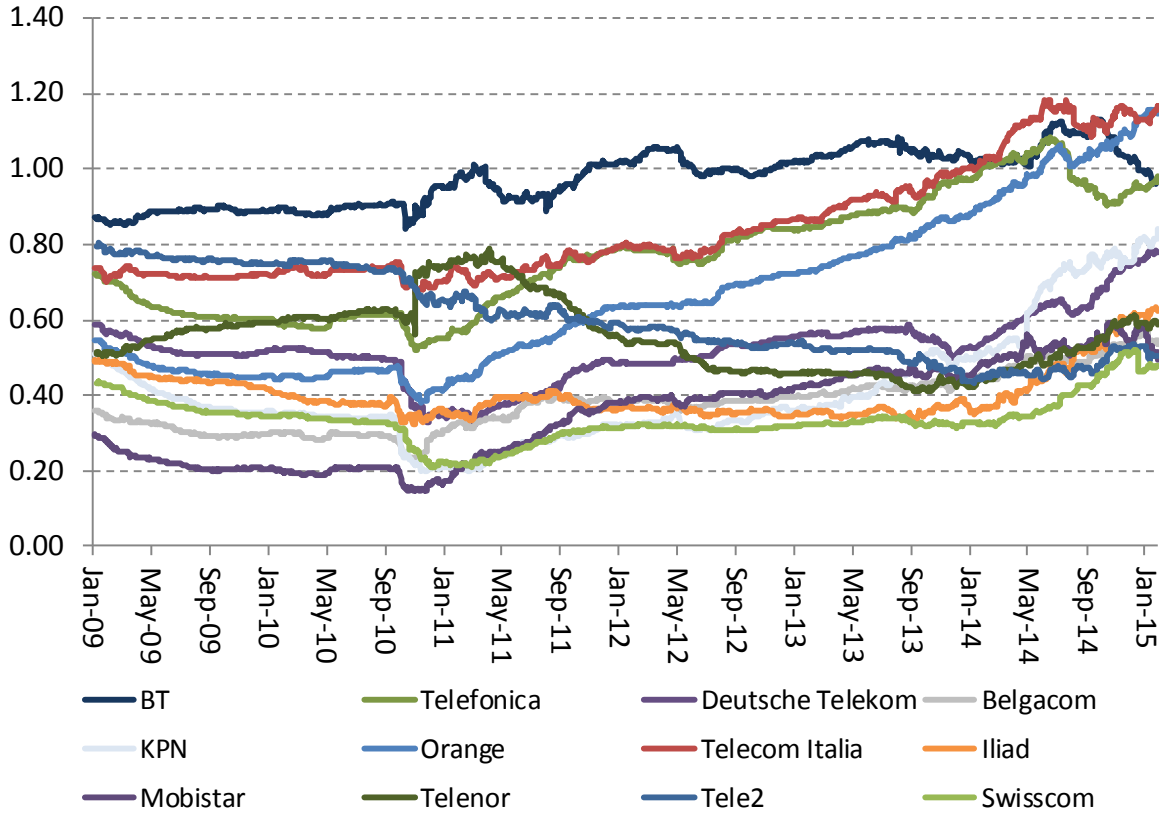
Table 3.3
EU Telcos Equity Beta against the FTSE All-Europe and FTSE All-World

		FTSE All Europe			FTSE All World	
		OLS/GLS*			OLS/GLS*	
		Beta	SE		Beta	SE
BT						
	1Y	0.61	0.08	1Y	0.73	0.12
	2Y*	0.65	0.06	2Y*	0.82	0.09
Telefonica SA						
	1Y	1.00	0.07	1Y	1.30	0.11
	2Y*	0.96	0.05	2Y	1.27	0.08
Deutche Telecom						
	1Y	0.98	0.08	1Y*	1.51	0.12
	2Y	0.78	0.06	2Y*	1.25	0.08
Belgacom SA						
	1Y	0.64	0.08	1Y	0.86	0.13
	2Y	0.54	0.07	2Y	0.73	0.10
KPN						
	1Y	1.02	0.11	1Y	1.39	0.16
	2Y	0.84	0.11	2Y	1.21	0.16
Orange SP						
	1Y	1.37	0.11	1Y	1.75	0.17
	2Y	1.15	0.07	2Y	1.51	0.11
Telecom Italia SpA						
	1Y	1.28	0.14	1Y	1.57	0.20
	2Y	1.16	0.11	2Y	1.49	0.16
Iliad SA						
	1Y	0.90	0.17	1Y	0.89	0.26
	2Y	0.62	0.10	2Y	0.68	0.15
Mobistar SA						
	1Y*	0.43	0.15	1Y*	0.41	0.22
	2Y	0.50	0.12	2Y	0.58	0.18
Telenor ASA						
	1Y	0.75	0.10	1Y	0.97	0.14
	2Y	0.59	0.06	2Y	0.78	0.08
Tele2 AB						
	1Y*	0.63	0.08	1Y*	0.78	0.12
	2Y	0.50	0.07	2Y	0.70	0.10
Swisscom AG						
	1Y*	0.54	0.07	1Y*	0.57	0.11
	2Y*	0.48	0.04	2Y*	0.58	0.06
EU Comparator Avg.						
	1Y	0.87		1Y	1.09	
	2Y	0.74		2Y	0.98	

*GLS Reported where regression diagnostics show heteroskedasticity/autocorrelation.
Source: NERA Calculation using Bloomberg data. Mobile share of revenue calculated as % of total revenue for FY 2013/14.

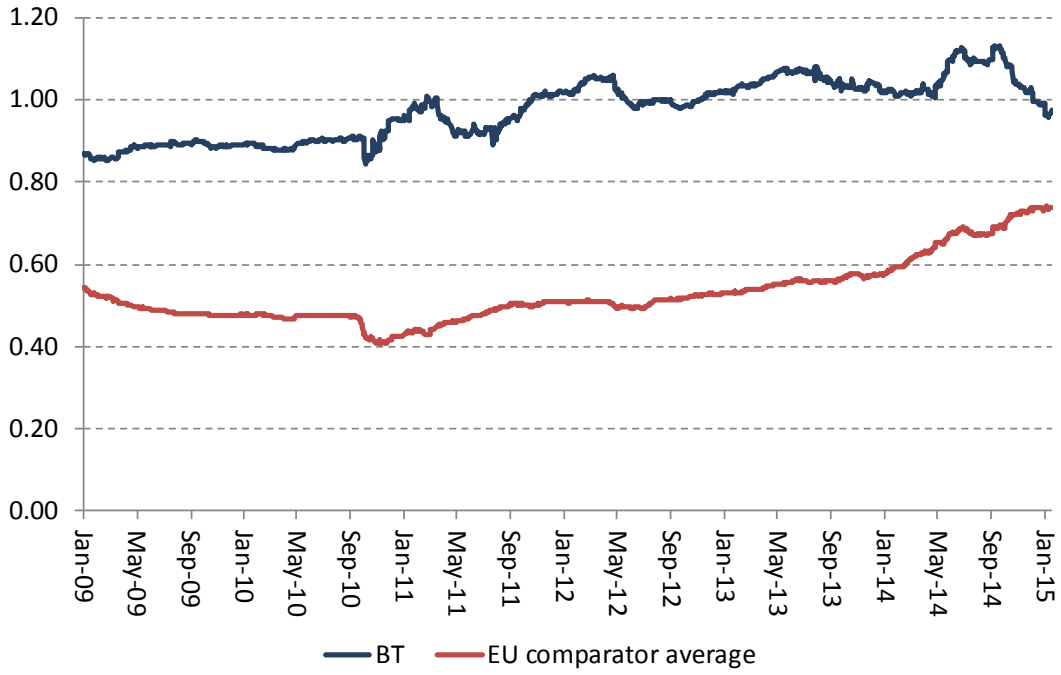
The following figures illustrate the change over time of the 2-year equity betas for European comparators. All equity betas for the European comparators set have generally exhibited an upward trend over the recent period, and particularly since 2014.

Figure 3.8
EU Telcos - 2Y Rolling Equity Beta



Note: In this chart, BT beta is calculated against FTSE All Share, while EU comparator betas are calculated against FTSE All Europe.
Source: NERA Analysis of Bloomberg data

Figure 3.9
BT vs.EU Telcos Average – 2Y Equity Beta

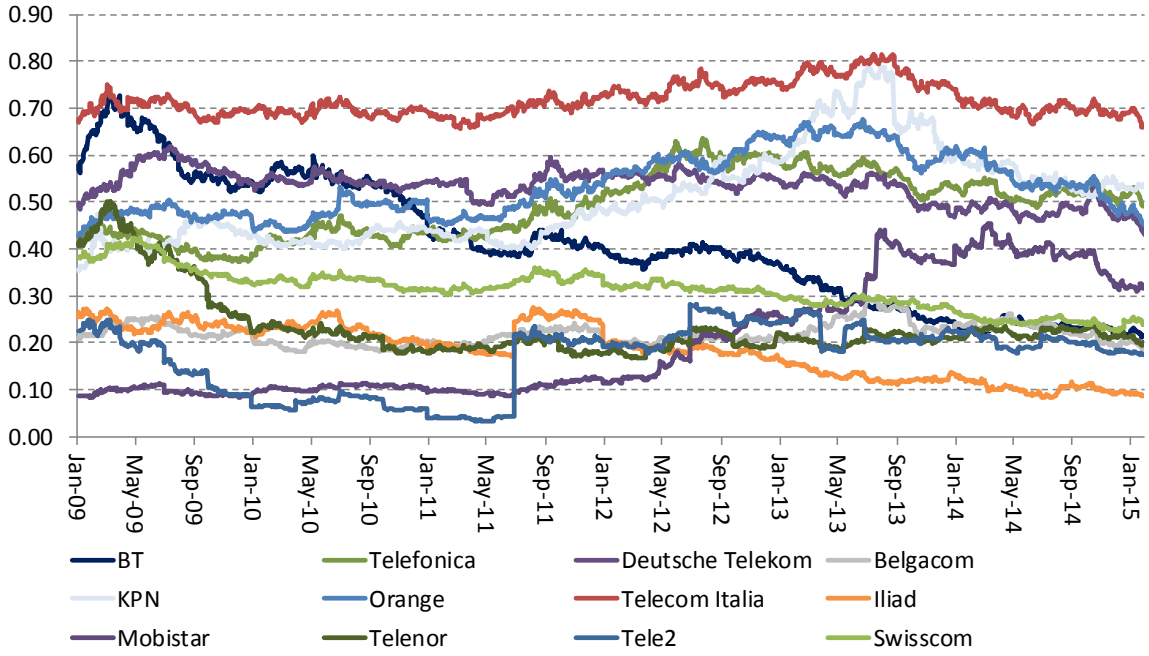


Note: in the chart, BT beta is calculated against FTSE All Share, while EU comparator betas are calculated against FTSE All Europe.
Source: NERA Analysis of Bloomberg data

3.2.2. Gearing and asset beta

In Figure 3.10 we plot the rolling gearing ratios for the set of European comparators over the period January 2009 to January 2015. As shown in Figure 3.10, there is a somewhat uniform decline in the EU comparators' gearing in the recent period, i.e. since late 2013/ early 2014.

Figure 3.10
EU Telcos Gearing Ratio



Source: NERA Analysis of Bloomberg data

Table 3.4 and Figure 3.11 below report asset betas for the set of European comparators. Our average 2-year asset beta for the eleven comparators is 0.44 against the FTSE All Europe, and 0.56 against the FTSE All World. Most companies have experienced an increase in the asset betas in 2014.

Table 3.4 also reports the shares of revenues coming from mobile services as a percentage of total revenues for each EU comparator, and Figure 3.13 shows the relationship graphically. While historically, fixed line services may have been perceived as a necessity with lower income elasticity when compared to mobile services and by extension a lower asset beta, the sample below does not strongly support this thesis. As shown in Figure 3.13, we do not observe a strong systematic pattern between the shares of mobile revenues and the accompanying asset betas in the present European sample of comparators.[24]

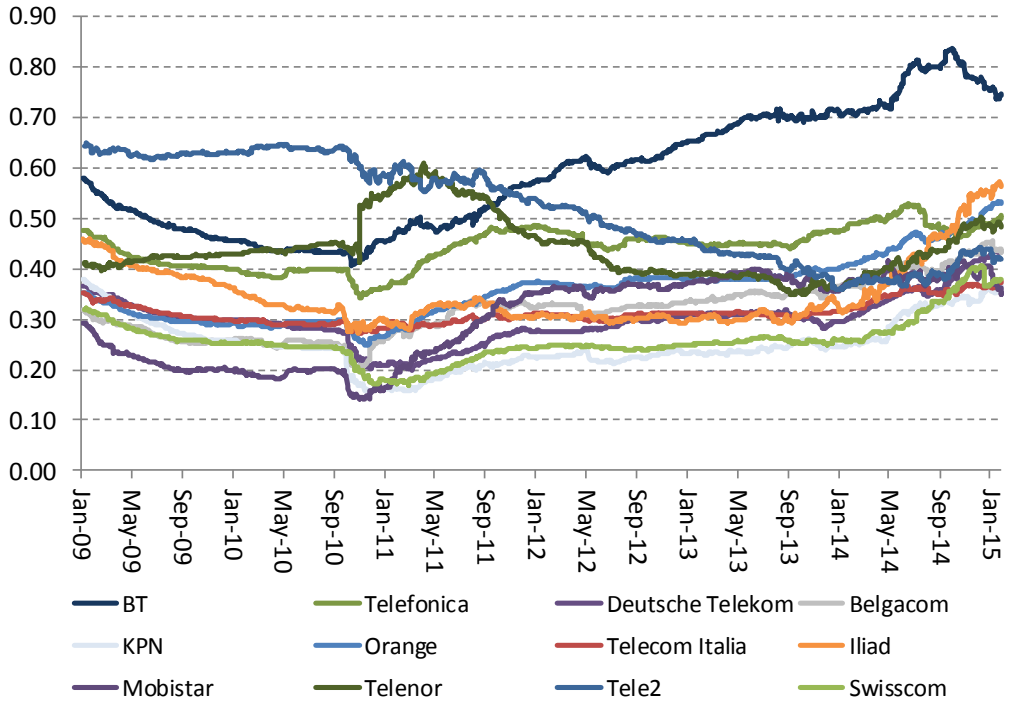
Table 3.4
EU Telcos Asset Beta against the FTSE All-Europe and FTSE All-World

		FTSE All Europe		FTSE All World		
	Gearing	Beta Debt = 0 OLS/GLS	Beta Debt= 0.1 OLS/GLS	Beta Debt= 0 OLS/GLS	Beta Debt = 0.1 OLS/GLS	% Mobile business
BT						
1Y	0.23	0.47	0.49	0.56	0.58	
2Y	0.26	0.48	0.51	0.61	0.64	
Telefonica SA						
1Y	0.52	0.48	0.53	0.62	0.68	
2Y	0.54	0.44	0.50	0.59	0.64	66.40%
Deutche Telecom						
1Y	0.48	0.51	0.55	0.78	0.83	
2Y	0.51	0.38	0.44	0.62	0.67	N/A
Belgacom SA						
1Y	0.22	0.50	0.52	0.67	0.69	
2Y	0.24	0.41	0.43	0.56	0.58	36.60%
KPN						
1Y	0.55	0.46	0.52	0.63	0.68	
2Y	0.64	0.31	0.37	0.44	0.50	66.90%
Orange SP						
1Y	0.54	0.63	0.69	0.81	0.86	
2Y	0.59	0.47	0.53	0.62	0.68	60.60%
Telecom Italia SpA						
1Y	0.70	0.39	0.46	0.48	0.55	
2Y	0.74	0.30	0.37	0.39	0.46	32.30%
Iliad SA						
1Y	0.10	0.81	0.82	0.80	0.81	
2Y	0.11	0.55	0.56	0.60	0.61	66.40%
Mobistar SA						
1Y	0.37	0.27	0.31	0.26	0.29	
2Y	0.37	0.31	0.35	0.36	0.40	90.30%
Telenor ASA						
1Y	0.22	0.58	0.61	0.75	0.78	
2Y	0.22	0.46	0.48	0.61	0.64	84.20%
Tele2 AB						
1Y	0.21	0.50	0.52	0.62	0.64	
2Y	0.21	0.40	0.42	0.55	0.57	71.90%
Swisscom AG						
1Y	0.27	0.39	0.42	0.42	0.44	
2Y	0.27	0.35	0.38	0.43	0.45	55.70%
EU Comparator Avg.						
1Y	0.38	0.50	0.54	0.62	0.66	
2Y	0.40	0.40	0.44	0.52	0.56	

*GLS Reported where if regression diagnostics show heteroskedasticity or autocorrelation.

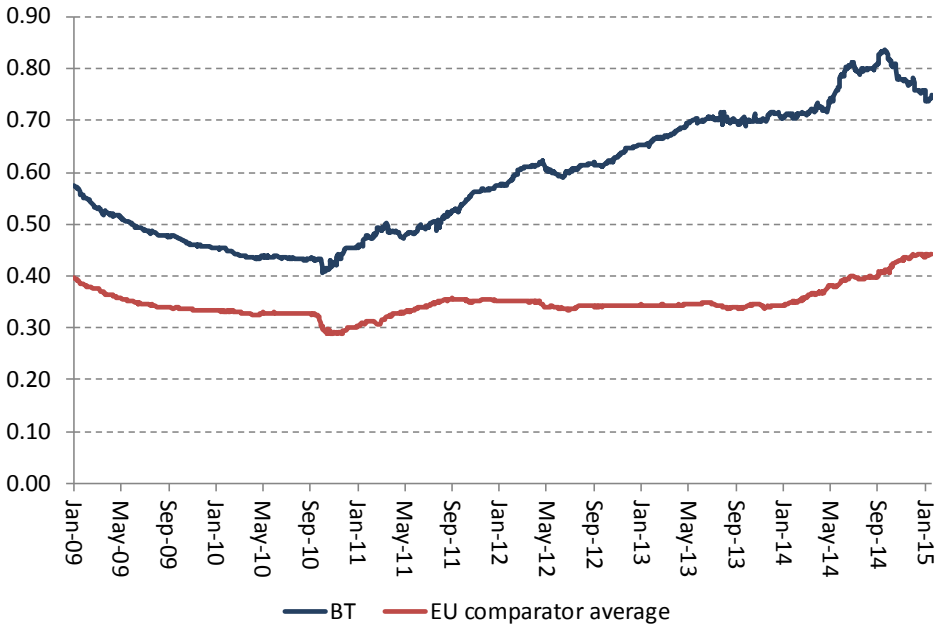
Source: NERA Calculation

Figure 3.11
EU Telcos - 2Y Rolling Asset Beta



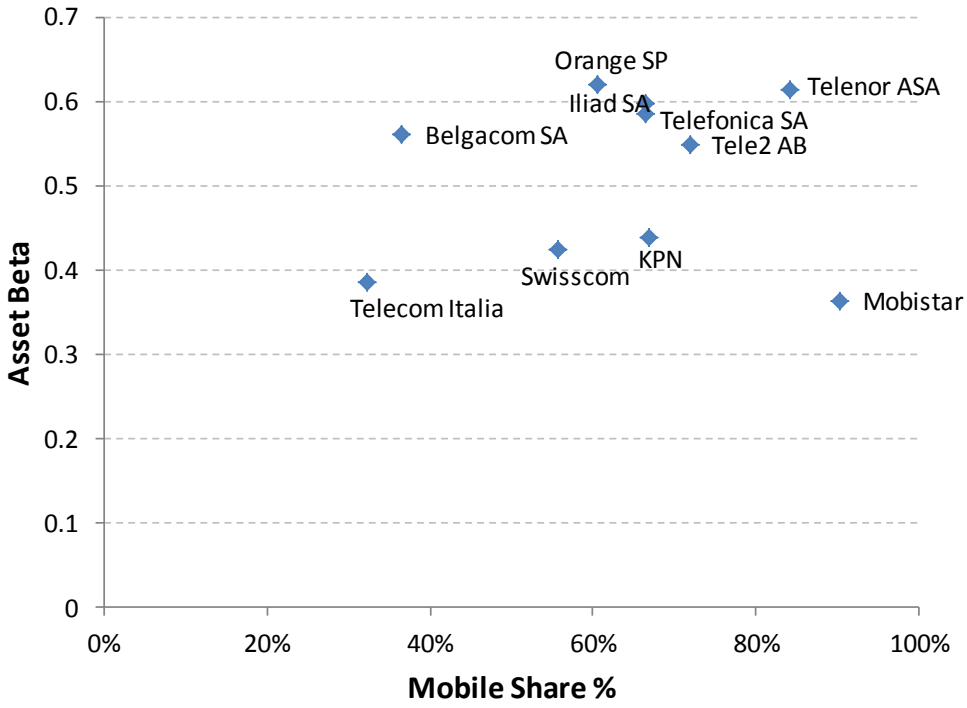
Note: in the chart, BT beta is calculated against FTSE All Share, while EU comparator betas are calculated against FTSE All Europe.
Source: NERA Analysis of Bloomberg data

Figure 3.12
BT vs. EU Telcos Average – 2Y Asset Beta



Note: in the chart, BT beta is calculated against FTSE All Share, while EU comparator betas are calculated against FTSE All Europe.
Source: NERA Analysis of Bloomberg data

Figure 3.13
Asset betas vs. Mobile Revenue shares for EU Comparators



Source: NERA Analysis of Bloomberg data

3.3. US Telcos

The US telcos reference sample includes five telecommunications companies, i.e. AT&T, Verizon, Time Warner Cable, Comcast, and Century Link.

3.3.1. Equity beta estimation

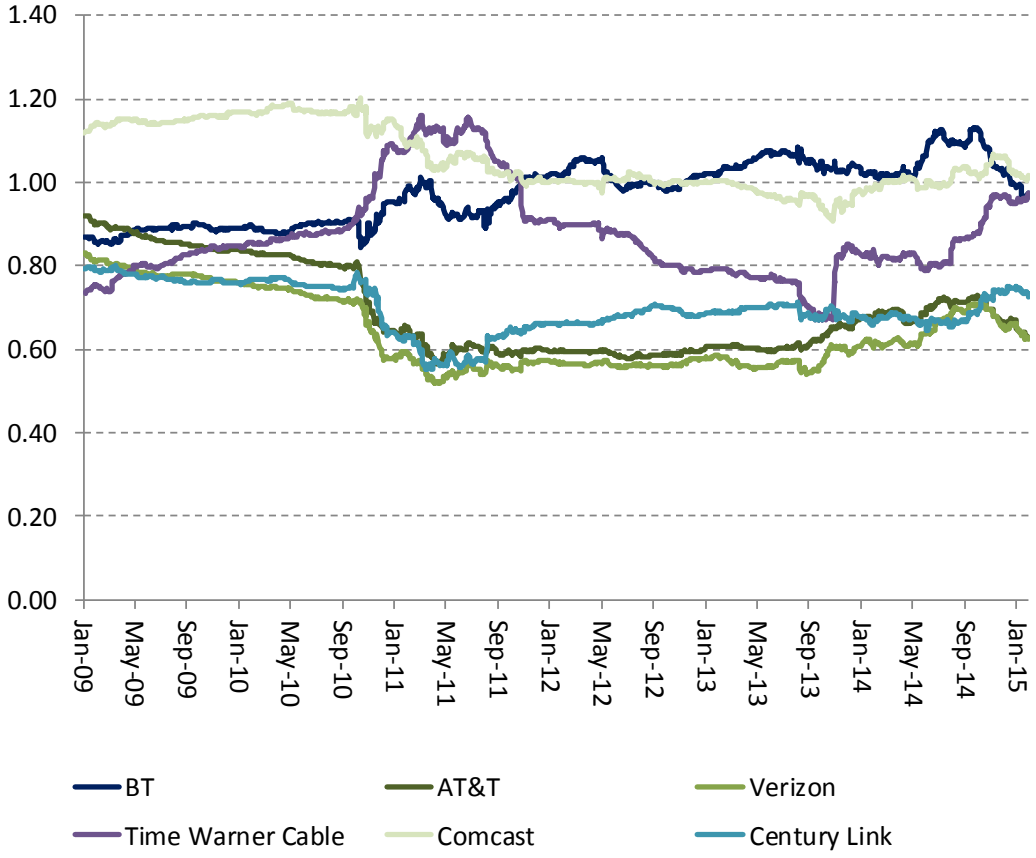
Table 3.5 and Figure 3.14 illustrate US comparators equity beta estimates against the S&P 500 index. The US comparator set displays a comparatively wide range of outcomes despite its reasonably small sample size. This wide dispersion indicates that there is a wide range of risk drivers (e.g. differing regulatory framework, market risk etc.) affecting the US comparator set, which may or may not be affecting BT. This reduces their reliability as indicators of the systematic risk for BT.

Table 3.5
US Telcos Equity Beta

		S&P 500	
		OLS / GLS*	
		Beta	SE
AT&T			
	1Y*	0.57	0.07
	2Y	0.63	0.05
Verizon			
	1Y*	0.61	0.07
	2Y	0.62	0.05
Time Warner Cable			
	1Y	1.05	0.09
	2Y	0.97	0.08
Comcast			
	1Y	1.01	0.08
	2Y	1.01	0.06
Century Link			
	1Y	0.67	0.09
	2Y	0.72	0.09
US Comparator Avg.			
	1Y	0.78	
	2Y	0.79	

*GLS Reported where regression diagnostics show heteroskedasticity/autocorrelation.
Source: NERA Calculation

Figure 3.14
US Telcos 2Y Rolling Equity Beta

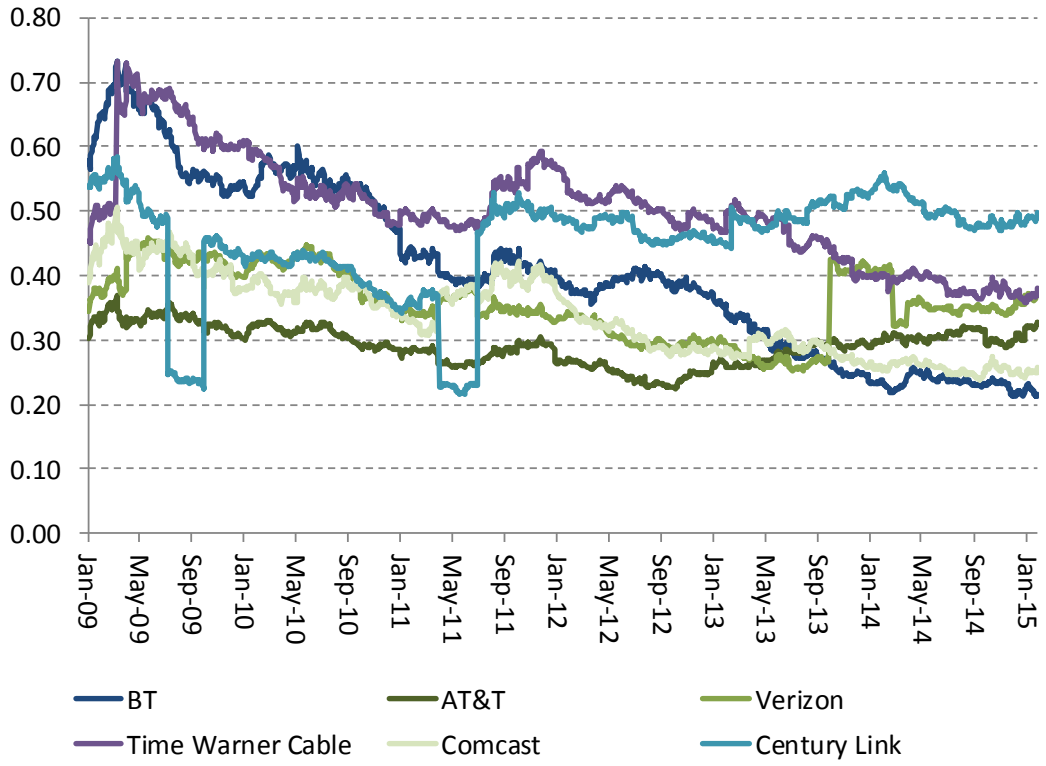


Note: In this chart, BT's beta is calculated against FTSE All Share, while US comparator betas are calculated against S&P 500.
Source: NERA Analysis of Bloomberg data

3.3.2. Gearing and asset beta

In Figure 3.15 we plot the rolling gearing ratios for the set of European comparators over the period January 2009 to January 2015.

Figure 3.15
US Telcos Gearing Ratios



Source: NERA Analysis of Bloomberg data
Note: Gearing data shown on a daily basis.[25]

Table 3.6 and Figure 3.16 below report current asset betas and 2-year rolling asset betas since 2009 for the set of US comparators. The current set of asset betas is again widely dispersed, which suggests that the observed dispersion in the equity betas shown above cannot be explained with differences in financial leverage only. We therefore consider that less weight should be placed on this set of comparators.

25 CenturyLink's gearing showed some abnormality around July 2009 and April 2011, both of which were associated with periods when the company was undergoing M&A deals. The jumps arise due to the fact that whilst market capitalization data is updated daily to reflect the change of outstanding shares, debt data is only updated at quarter end, a mismatch which causes the abnormality of gearing during the deal period.

2 July 2009: CenturyTel and Embarq merged to become CenturyLink. http://www.bizjournals.com/kansascity/stories/2009/06/01/daily21.html

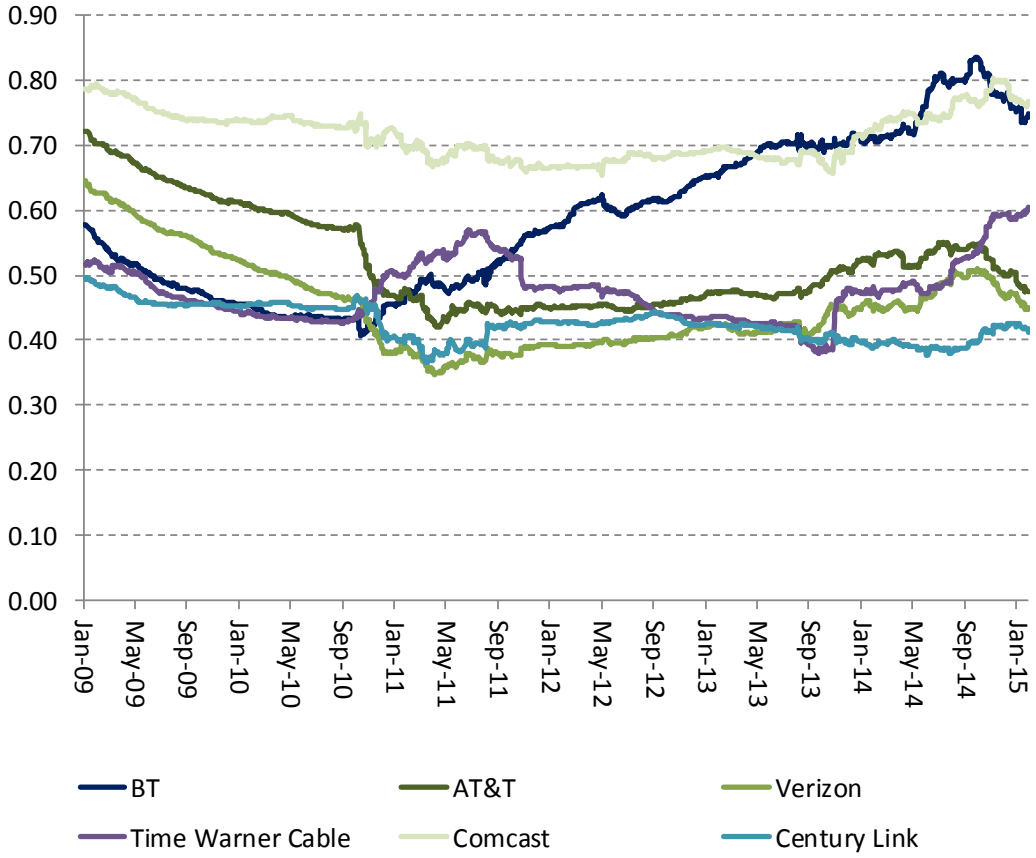
1 April 2011: CenturyLink took over Qwest. http://washingtontechnology.com/articles/2011/04/04/qwest-centurylink-deal-close.aspx

Table 3.6
US Telcos Asset Beta against the S&P 500

			S&P 500		
		Gearing	Beta Debt=0 OLS/GLS	Beta Debt=0.1 OLS/GLS	% Mobile business
AT&T					
	1Y	0.31	0.39	0.42	
	2Y	0.29	0.44	0.47	54.30%
Verizon					
	1Y	0.35	0.39	0.43	
	2Y	0.34	0.41	0.45	67.40%
Time Warner Cable					
	1Y	0.38	0.65	0.68	
	2Y	0.42	0.56	0.60	N/A
Comcast					
	1Y	0.26	0.75	0.78	
	2Y	0.27	0.74	0.76	N/A
Century Link					
	1Y	0.50	0.34	0.39	
	2Y	0.50	0.36	0.41	N/A
US Comparator Avg.					
	1Y	0.36	0.50	0.54	
	2Y	0.37	0.50	0.54	

*GLS Reported where regression diagnostics show heteroskedasticity/autocorrelation.
Source: NERA calculation

Figure 3.16
US Telcos 2Y Rolling Asset Beta



Note: in the chart, BT beta is calculated against FTSE All Share, while US comparator betas are calculated against S&P 500.
Source: NERA Analysis of Bloomberg data

4. Further Analysis of BT's Asset Beta

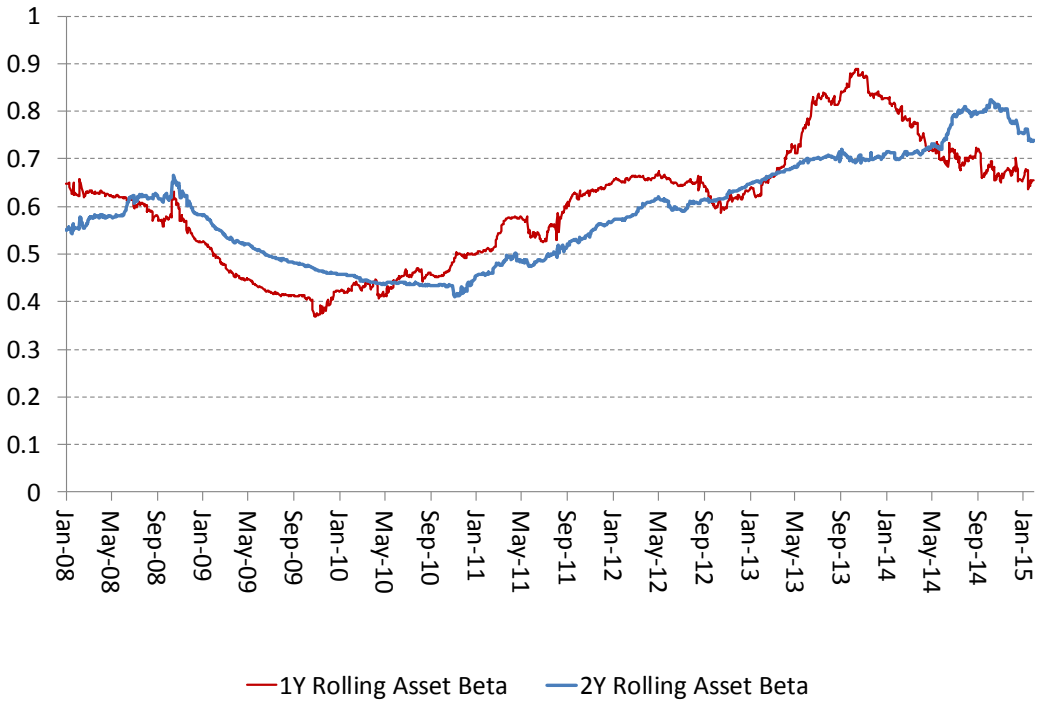
This section assesses in more detail the changes in BT's asset beta, and provides a commentary on the structural changes in the asset beta in light of BT's business development in recent years.

4.1. BT's 1-year and 2-year OLS Asset Betas

At the last review, Ofcom's consultants focused on the 1-year and 2-year OLS estimates of BT's beta, an update of which is shown in Figure 4.1. Both the 1-year and the 2-year asset betas against the FTSE All Share have been increasing over the period from 2010 / 2011, exhibiting a change from around 0.4 / 0.5 to around 0.8/ 0.9 for both the 1-year and 2-year betas.

However, the 1-year beta has decreased from late 2013 and the 2-year beta has decreased from late 2014. The recent decline is therefore in contrast to the long-term increase in BT's beta observed over much of the period shown.

Figure 4.1
BT Rolling 2Y Asset Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

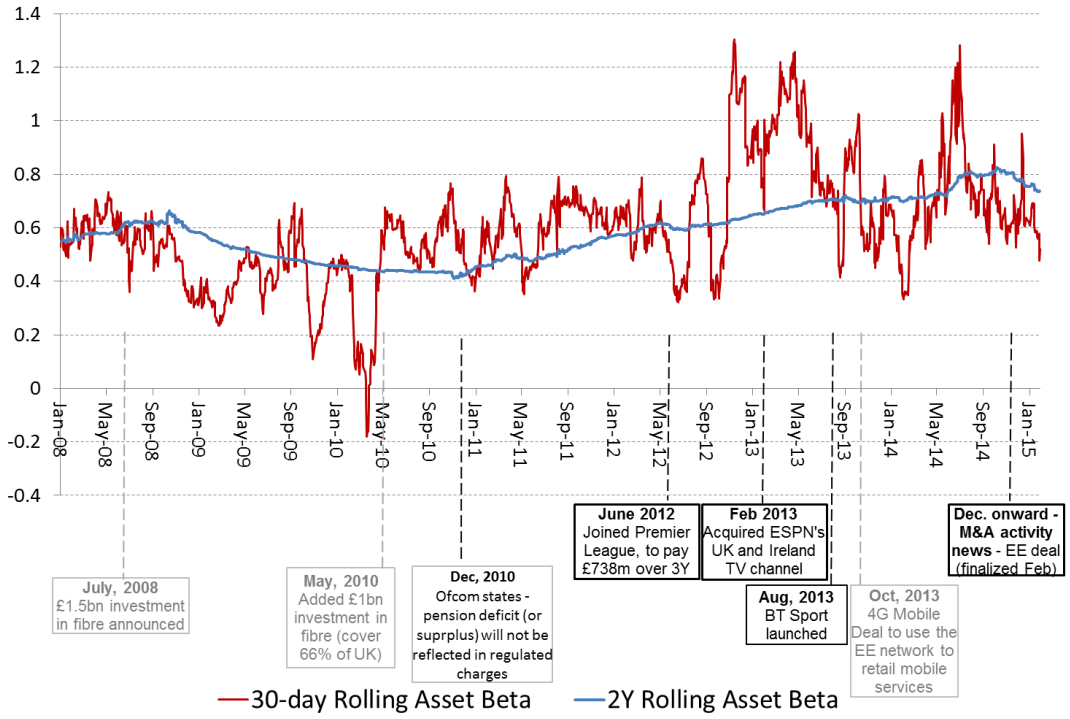
As we discussed in section 2.2 above, because the OLS technique attaches the same weight to each observation point within an estimation window, the 1-year and 2-year OLS estimates do not respond quickly to new market information that affects the betas. In the next sections, we explore alternative methods of estimating beta risk, i.e. we assess (1) short-term correlations

and (2) alternative beta estimates based on the Kalman Filtering procedure, to understand the drivers of the changes in systematic risk evident in BT's beta.

4.2. BT 30-day Asset Beta

Figure 4.2 below reports BT's 30-day rolling asset beta which provides an indication of the more immediate perception of market risk by investors, since it is based on the most immediate short-term (30 days) estimation window. Figure 4.2 also provides context for the changes in risk observed in the short-term correlations by relating the 30-day rolling beta to some key announcements that may have affected BT's systematic risk.

Figure 4.2
BT Rolling 30-day Asset Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

As evidenced from Figure 4.2 above, BT's 30-day beta, whilst volatile, was lower over the period from early 2008 to early 2010, and the 2-year average was declining over the same period. This happened to be at a time when BT made its first large fibre-to-the-cabinet (FTTC) technology investment in July 2008, with which BT entered the market for higher speed broadband. An ex ante assessment of the effect from this investment may have been that BT's systematic risk would increase around the announcement of these investments in the FTTC network. The programme was capital intensive[26], and the cashflows that were to be

[26] An assessment of BT's actual capex profile over the period suggests that BT's Openreach capex didn't experience significant changes over the period, as the fibre investment was accompanied by a scale down of the capex on the copper network. See BT Annual Reports 2008 - 2014.

generated with the fibre investment may well have been perceived to be subject to greater risk than other investments in Openreach – i.e. the FTTC network was a new product, intended to deliver higher speed and better quality of service, albeit also at a higher price. In that sense, at least during its introductory phase, the FTTC investment could have been perceived as having a high income elasticity and therefore greater systematic risk. We therefore believe that the decline in BT's beta over the 2008-2010 period strongly indicated by the 2-year OLS in Figure 4.2 is more likely to be associated with changes in perceptions of relative risk following the Global Financial Crisis (GFC). Over this period, BT also issued two profit warnings as a result of poor performance in its Global Services division, the effect of which is further explored in section 4.3.

BT's short-term asset beta shifted to higher levels from mid/late-2010. Several events could have concurrently triggered and sustained the observed increase in BT's asset beta, which we discuss below.

First, BT continued its FTTC expansion, announcing in May 2010 intentions to further expand its superfast broadband network to cover 66% of the UK by 2015, [27] which would have affected the beta to the extent that the fibre network service was perceived as more income elastic and therefore exposed BT to greater systematic risk, as discussed above.

Second, BT runs one of the largest Defined Benefit (DB) pension schemes of the FTSE 100 group.[28] An emerging academic literature exists which documents empirical findings that equity risk may reflect the riskiness of a company's pension plan.[29] According to this literature, the net risk contributions from a company's pension plan are crucially driven by (1) the relative value of the pension assets to operating assets of the business (i.e. debt and equity net of the difference between pension assets and pension liabilities), and (2) the relative systematic risk (quantified by the beta parameter) of the pension assets and liabilities.[30] Our empirical assessment suggests that BT's ratio of pension assets to operating assets has been increasing in the last several years, which according to this literature would imply an increasing risk contribution from the pension scheme. [31] However, the size of the

---

[27] ITPRO (13 May 2010): "BT adds £1 billion to fibre rollout to cover two-thirds of UK". Source: http://www.itpro.co.uk/623254/bt-adds-1-billion-to-fibre-rollout-to-cover-two-thirds-of-uk

[28] As at 30 September 2014, JLT Employee Benefits reported BT's pension liability as the second largest amongst the FTSE 100 Group at £47,135million. See JLT Employee Benefits in association with J.P.Morgan Cazenove, The FTSE 100 and their pension disclosures.

[29] See Jin li et al (2006), "Do a firm's equity returns reflect the risk of its pension plan?", *Journal of Financial Economics, 81 (2006)*, p. 1-26.

[30] For an accessible exposition, see Ian Cooper (2 September 2009), *The effect of defined benefit pension plans on measurement of the cost of capital for UK regulated companies, A report for Ofcom, accessed here:* http://stakeholders.ofcom.org.uk/binaries/consultations/btpensions/annexes/cooper_report.pdf

The pension risk contribution according to this literature is defined as:

$$\beta_{pension} = \beta_{pension_assets}\frac{PA}{D+E} - \beta_{pension_liabilities}\frac{PL}{D+E}$$

Where PA is the total value of the Pension Assets; PL is the total value of the Pension Liabilities, D is the value of debt E is the value of equity net of the pension surplus/deficit, and $\beta_{pension_assets}$ and $\beta_{pension_liabilities}$ are the systematic risk of the pension assets and liabilities respectively.

[31] From BT's Annual Accounts (2009 – 2014), we estimate that the implied ratio of BT's Pension Assets to Operating assets (debt and equity of the operating business) has been on the rise since 2009, increasing from 116% in 2009 to

effect of the pension scheme on a company's asset beta is uncertain and difficult to estimate.[32] We also note that Ofcom's December 2010 Pension Statement may have contributed as a (short-term) trigger event of an increase in the beta, in confirming deficit repair payments would not be reflected in regulated charges and that Ofcom would not adjust the WACC to reflect BT's defined benefit pension scheme.

Third, BT issued two profit warnings in October 2008 and January 2009 (see next section), due to poor performance in its Global Services (GS) unit. BT subsequently took steps to scale down the risk exposure from its GS unit, changing its head of GS, and embarking on cost control programmes and selective deal-making with multinationals.[33,34] BT Annual reports data shows that in the subsequent years following the profit warnings, BT GS' share of EBITDA has been steadily rising at the expense of BT Wholesale, which contains part of the regulated leased lines business (see Appendix D). This could have been contributing to an increase in BT Group's overall asset beta, to the extent that the GS unit would be exposed to higher systematic risk than other parts of BT.

Fourth, and more recently, BT's short-term systematic risk has significantly spiked around the announcements of investments in the pay-television content market.[35] BT commenced its investment in BT Sport in early 2013, just over half a year from its acquisition of the rights to screen certain live Premier League matches, where it faces significant competition from Sky. The increase in BT's beta around the BT sport investments could have been driven by the perception of the riskiness of this investment, given that it entailed entry into a competitive market where BT would have to carve its market share from established incumbents such as Sky and others.[36] BT's systematic risk from this activity would have likely differed from that of Sky which has seen a rather stable asset beta over the same period, given that BT faced much greater uncertainty around the likelihood of establishing itself as a successful player in this market, with Sky as the incumbent player. The effect of investment in BT Sport on the beta is supported by the empirical evidence. The 30-day beta estimate increased in early/mid-2013, around the time when BT fully clarified its BT Sport expansion, as shown in Figure 4.2 above.

Following the above increase in the asset beta, BT's 30-day asset beta was then very volatile during 2014, shifting between 0.4 and 1.2. It is hard to ascribe a clear impact to the changes

---

224% in 2014. Since pension assets have typically higher asset betas than pension liabilities, this would increase the risk contribution from the pension plan (see fn. 30 above).

32 For a discussion of the measuring issues, see ibid., p.3.

33 Financial Times (9 Jan 2010), Eyebrows raised by switch at BT Global Services, http://www.ft.com/cms/s/0/23130302-fcbf-11de-bc51-00144feab49a.html#axzz3Uvfa4zEH

34 Note that the share of revenues from Global Services only started declining from 2012, see Appendix D.

35 FT (31 January 2014): "BT reaps benefits from pay-TV drive". Source: http://www.ft.com/cms/s/0/047725ba-8a4e-11e3-9c29-00144feab7de.html#axzz3TF1B0Muv

36 This was already recognized at the time, see for e.g. the Telegraph (2012) writing: "..With its big money move into sports broadcasting, the risk profile of BT Group has increased. This has left some investors concerned that, ultimately, its dividend could be at risk…the problem with sports broadcasting is the cost – and the fact that Sky is light years ahead after throwing money around for more than a decade…There is a good argument that the strategy [rugby/football Premier League rights] could prevent "churn" – the amount of customers cancelling their contract. However, BT's offering needs to be as good as that seen on Sky to achieve this." Accessed at: http://www.telegraph.co.uk/finance/markets/questor/9551240/Questor-share-tip-Hold-BT-Group-as-sports-move-increases-risk.html

over this period as there were not any obvious events affecting BT in mid-2014 that appeared to cause the spike in the beta at this time.

We note also that at the end of 2014, BT confirmed its interest in EE, the UK mobile operator,[37] which it confirmed in February 2015. This investment allows BT to increase its mobile market share and also offer quad-play services. To the extent that mobile operations are associated with a lower systematic risk to the rest of BT, the acquisition of EE would be expected to reduce the BT Group asset beta.

4.3. Kalman Filter

To cross-check the evidence from the short-window (30-day) and longer-window (1-year, 2-year) OLS estimation techniques, we compare the beta estimates to those estimated via a Kalman Filter technique, shown in Figure 4.3. Similar to the short-term 30-day OLS, the Kalman technique is able to more quickly internalize changes in the beta, but has the added advantage that it is more stable than the 30-day OLS in that it distinguishes between "noise" and "systematic risk" in the short-term beta correlations.

The Kalman Filter supports the intuition observed via the short-term 30-day correlation, as shown in Figure 4.3, highlighting the following:

- The Kalman filtered beta suggests an increase in BT's beta since early 2009. The rise in BT's beta however, was preceded by a profit warning in October 2008, and again in January 2009, due to poor performance in Global Services, its largest business unit by revenue, which caused a massive drop in BT's share price (indicated by the strong fluctuations around the date in Figure 4.3).[38] As discussed above, BT subsequently implemented cost control programmes in GS, increasing its GS share of EBITDA which could have been contributing to increasing systematic risk, and as is corroborated by the Kalman filtered beta which has been increasing since late 2010;
- Systematic risk appears to have been on the rise furthermore since late 2010, coinciding with the announcements of investments in the FTTC technology; however, over the same period, the risk contribution of BT's DB pension plan could have been increasing (see discussion in section 4.2 above) and BT had an increasing share of EBITDA coming from the GS unit – all of which would have been putting an upward pressure on BT's beta (see discussion above);
- The Kalman filtered asset beta shows a most pronounced increase around BT's entry into the content market, and specifically around the BT Sports announcements from late 2012/ early 2013. This is consistent with the view that at the time, BT Sports may have been viewed by investors as increasing risk. Notwithstanding this observation, the Kalman filtered asset beta was on the rise since late 2010, during which time other events may have been also placing an upward pressure on the beta as discussed above;

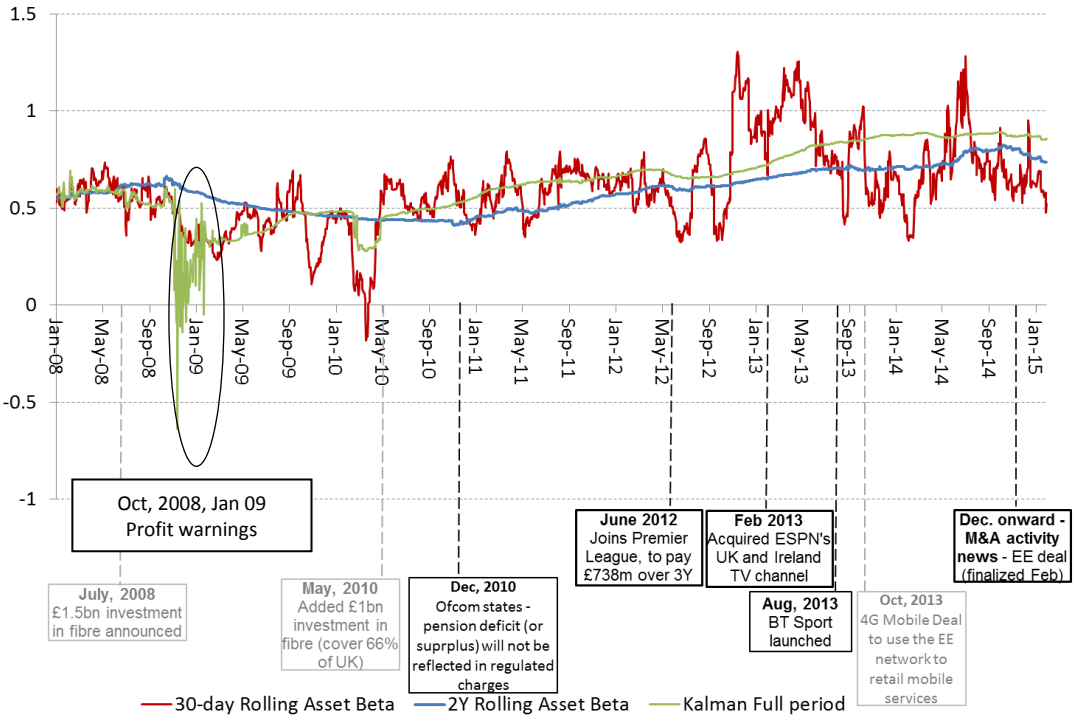
---

[37] FT (16 December 2014): "Analysts and investors welcome BT's move for EE". Source: http://www.ft.com/cms/s/0/9cbbf53c-8537-11e4-ab4e-00144feabdc0.html?siteedition=uk#axzz3TF1B0Muv

[38] BBC News (31 Oct 2008), BT shares slump on profit warning, http://news.bbc.co.uk/1/hi/business/7701626.stm

- BT's asset beta when estimated using a Kalman Filter appears to have stabilised at just over 0.8; and
- BT's stock will have also been affected recently by news of M&A activity, culminating in BT's deal with EE in February 2015[39]. As we discussed above, BT's exposure to the mobile market may be seen as decreasing beta risk to the extent that EE's asset beta is lower than that of BT Group, which again is supported by both the 30-day beta as well as the Kalman filtered beta which are both decreasing in the recent period around these announcements.

Figure 4.3
BT Rolling 30D vs. Kalman Filtered Asset Beta against FTSE All Share



Source: NERA Analysis of Bloomberg data

[39] See Financial Times (5 February 2015): "BT seals £12.5bn deal to buy EE"

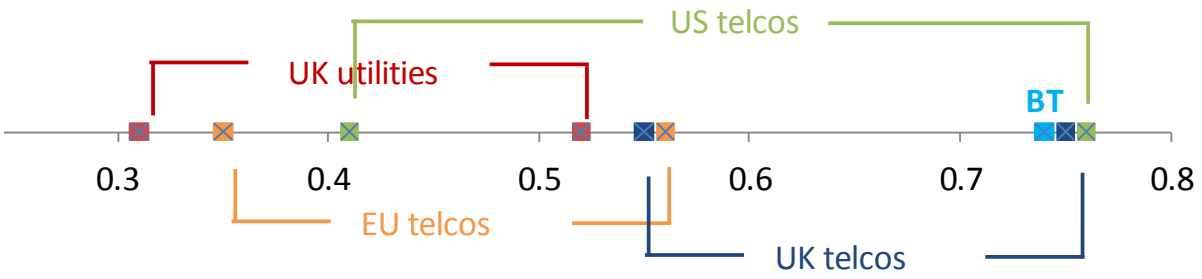
5. Conclusions

As per our terms of reference discussed in section 1 above, the analysis in this report focused on (1) assessing and validating Ofcom's previous approach to calculating betas in the telecommunications sector, which we discussed in section 2 above, and (2) updating Ofcom's previous analysis of BT's equity and asset betas, as well as the betas for comparator telecommunications companies, undertaken by its previous consultants, the Brattle Group, which we discussed in section 3 above.

Previous work by Ofcom focused on assessing 2-year OLS estimates of the asset and equity betas for BT and comparators. In this section we summarize our updated 2-year asset betas for BT and its comparators (assuming a debt beta of 0.1), shown on the spectrum chart below.

Figure 5.1 shows asset betas for BT and comparators, where BT's asset beta and the asset betas for the UK comparators are calculated against the FTSE All Share index, and the EU and US comparator asset betas are calculated against their respective domestic / regional indices. BT's asset beta of 0.74 is currently higher than that of any UK utility or EU telco comparator in our sample and lies close to the upper bound of UK and US telcos' asset beta ranges.

Figure 5.1
2Y Asset Beta Spectrum for BT and comparators



Source: NERA Analysis of Bloomberg data

BT's asset beta is currently slightly higher compared to Ofcom's previous update, though has been on the rise over the majority of the period since late 2010. In this report (section 4) we also investigated the potential drivers of the changes in BT's asset beta, using different methods including an assessment of short-term (30-day) beta correlations as well as the Kalman filtering technique.

Our assessment shows the following :

- Some of the increase in BT's asset beta risk may be associated with BT's entry into the content market and particularly the launch of BT sport, which is suggested by the spikes in the 30-day OLS beta and an increase in the Kalman filtered beta. The 2-year OLS, by construction is less sensitive to new information, and so is unable to pick up this change

in risk until much later when the heightened correlation between BT's stock price and the relevant index become a much larger portion of the sample.

- BT's asset beta in fact started increasing earlier, around BT's announcements of changing strategy in its Global Services business unit (indicated by the Kalman filter, commencing in early 2009), and was sustained over a period when the risk contribution of BT's DB pension plan could have been increasing, and BT made further announcements around the purchase of fibre networks (indicated by all asset beta measures, commencing from mid-2010); however, this increase was much more gradual and happened during the GFC, which was characterized by changing correlations in capital markets and heightened market volatility. Therefore, it is difficult to single out the effect from any individual event as the definitive driver of the change in BT's systematic risk, to the extent that these occurred over a period of heightened macroeconomic uncertainty.
- More recently, BT's beta has been trending downward. The trend has been observed only recently and is therefore difficult to attribute to any specific factor; however, the following events could have contributed to the decline, and may be worth monitoring:
  - Market perception of the riskiness of BT Sport may have declined, due to BT establishing a stable share in the content market, and engaging in successful rights auctions; and
  - The proposed acquisition of EE, the UK's largest mobile operator, allows BT to increase its mobile market share and also offer quad-play services. To the extent that mobile operations are associated with a lower systematic risk to the rest of BT, the acquisition of EE would be expected to reduce the BT Group asset beta, which is consistent with the empirical observations.

Appendix A. Statistical Tests

A.1. Visual Inspection of the data

As the first step in our statistical analysis, we visually inspect the data to detect any obvious violation of the OLS assumptions.

In the charts below, we show for each 2-year equity beta regression of the UK comparator sample the results of the following analysis:

1) a histogram of residuals, to assess evidence on the normality of the error terms;

2) a scatter plot of residuals and their lagged values to assess any positive/negative dependence which would be indicative of autocorrelation of the error terms;

3) a scatter plot of the residuals through time, to assess whether the variance of the error term appears constant through time (homoscedasticity); and

4) a scatter plot with fitted value on the X-axis and residual on the Y-axis, to assess whether the variation of the error term is systematically different when the independent variable changes value.

The charts below do not exhibit systematic relationships which would indicate a violation of the OLS assumptions. We carry out further statistical tests in the following sections to assess these findings more formally.

Figure A.1
BT

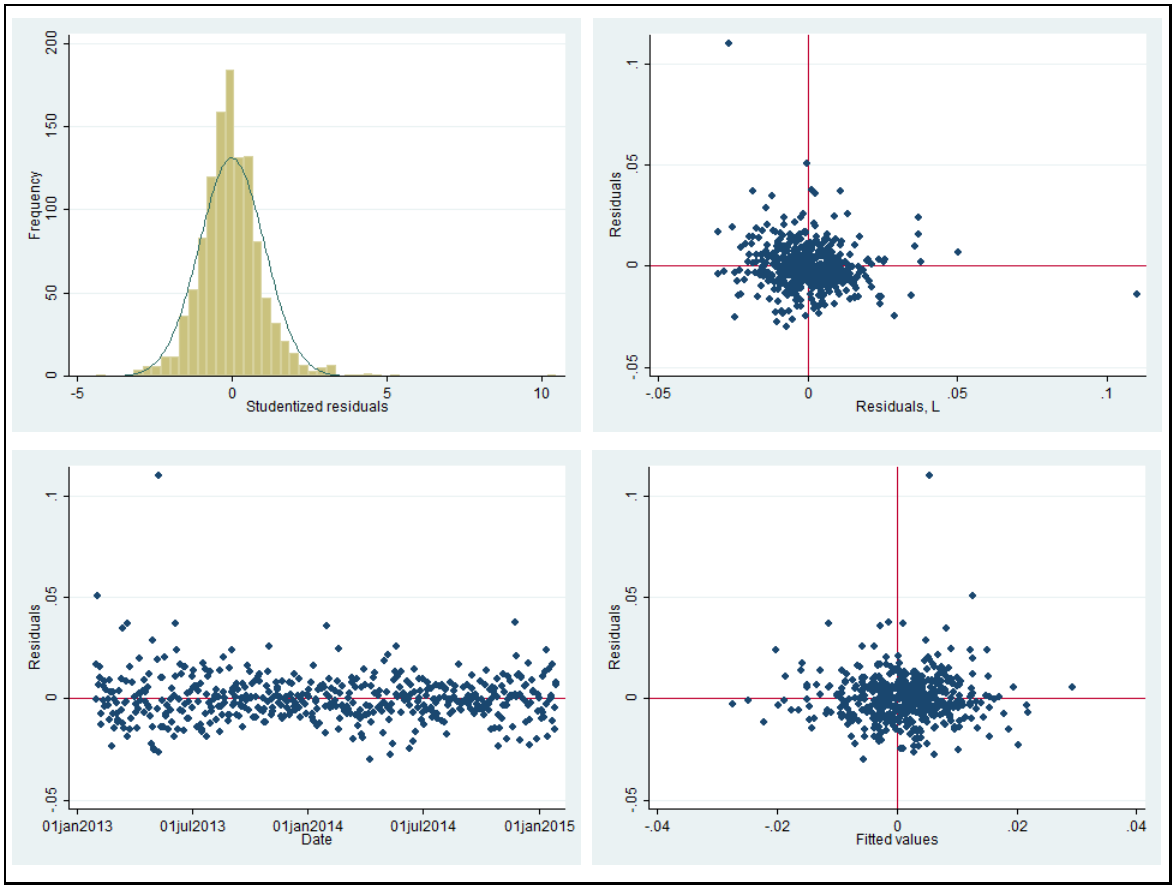

Frequency
0
50
100
150
200
-5
0
5
10
Studentized residuals
Residuals
-.05
0
.05
.1
-.05
0
.05
.1
Residuals, L
Residuals
-.05
0
.05
.1
01jan2013
01jul2013
01jan2014
01jul2014
01jan2015
Date
Residuals
-.05
0
.05
.1
-.04
-.02
0
.02
.04
Fitted values

Figure A.2
National Grid

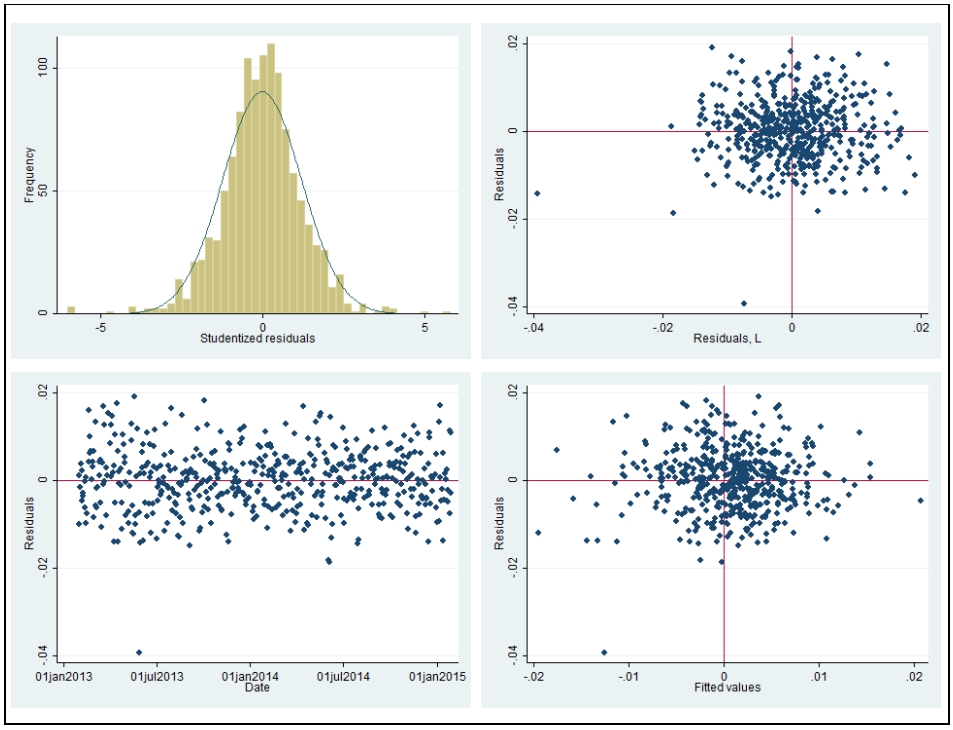


Figure A.3
Severn Trent

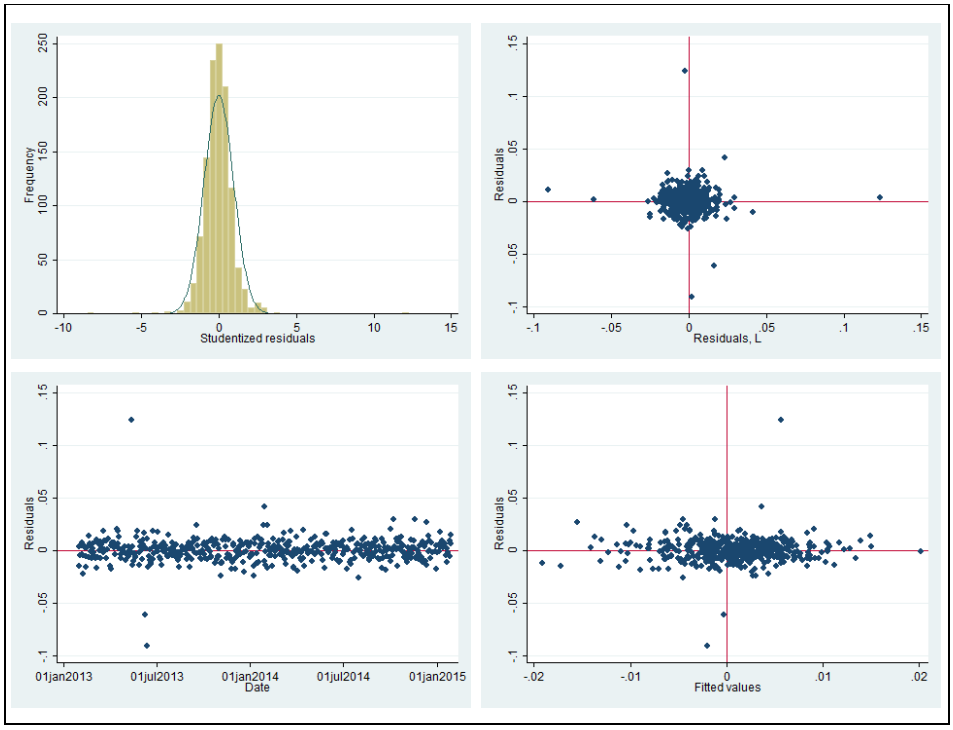


Figure A.4
Pennon

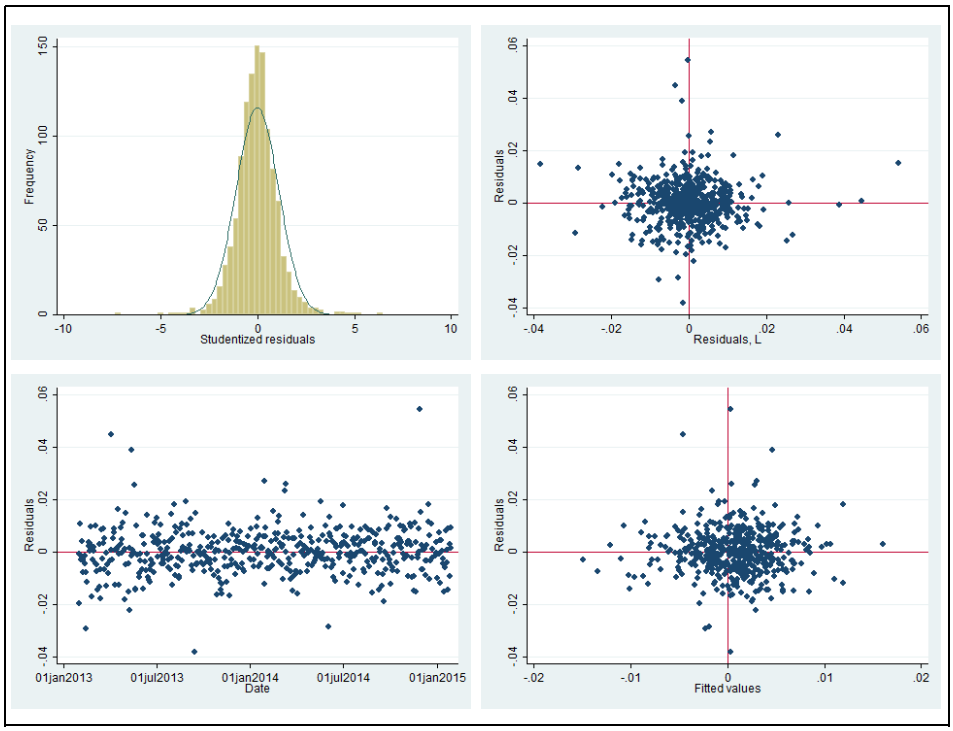


Figure A.5
United Utilities

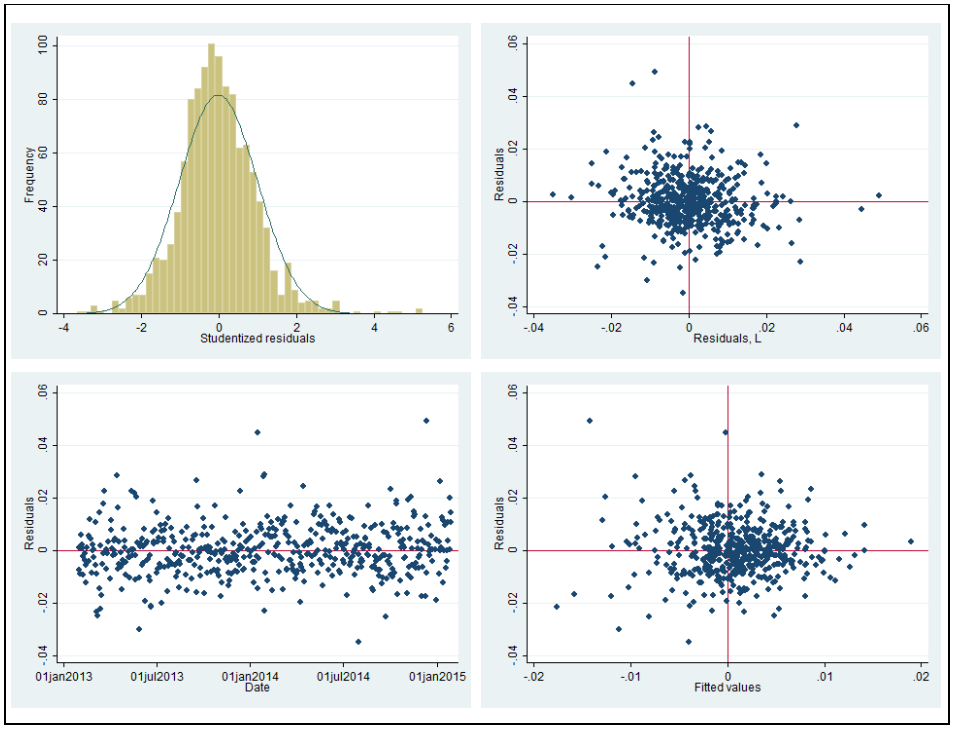


Figure A.6
Centrica

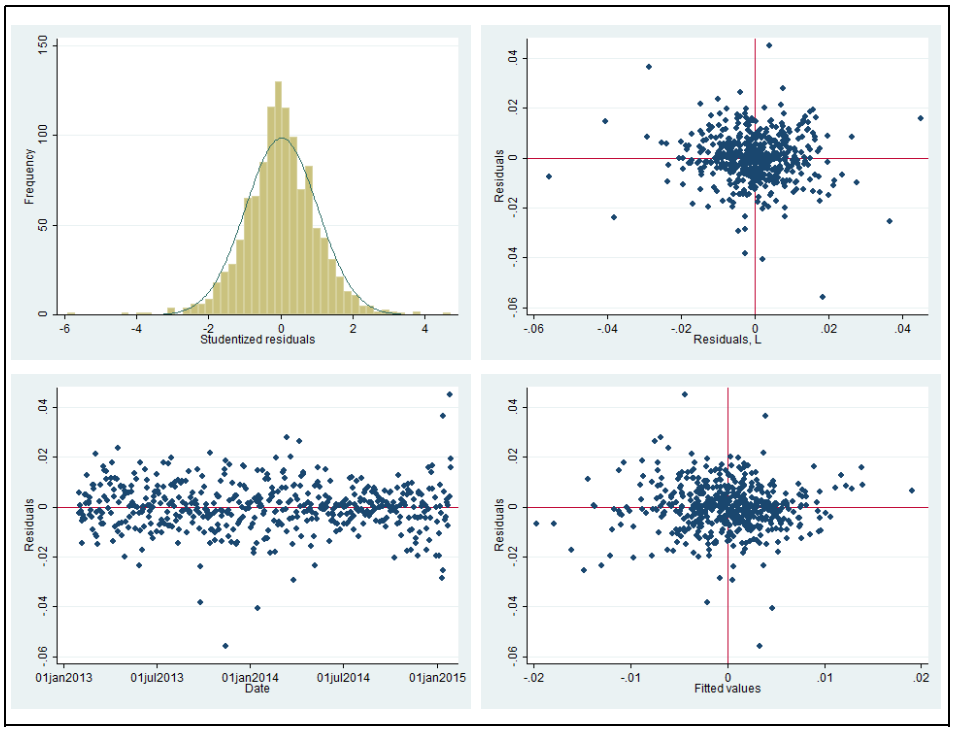


Figure A.7
SSE

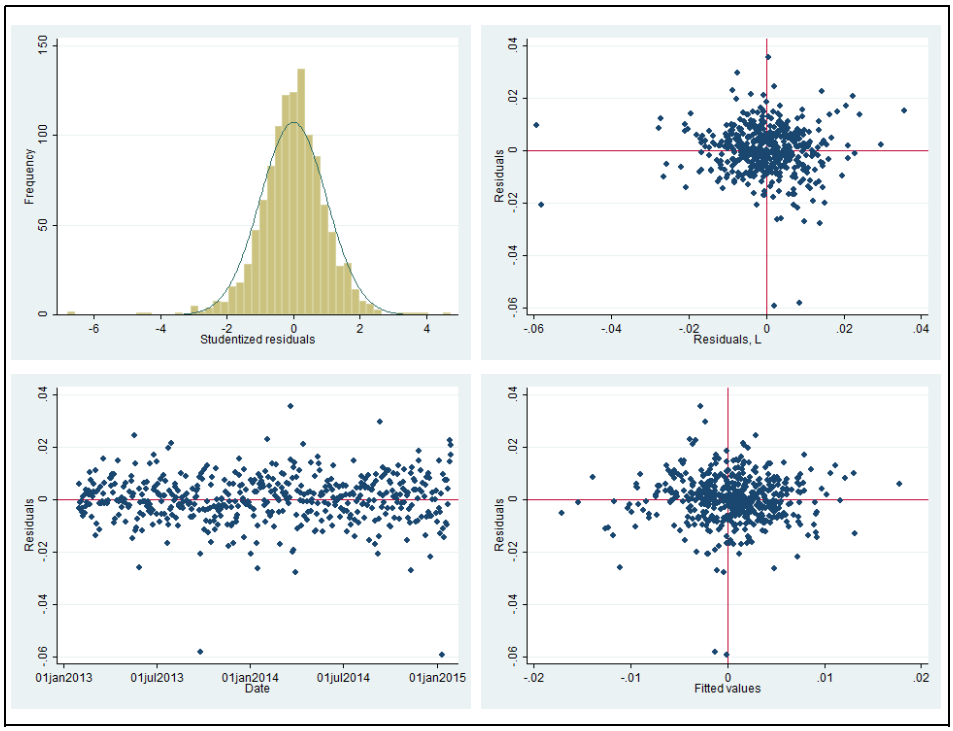


Figure A.8
TalkTalk

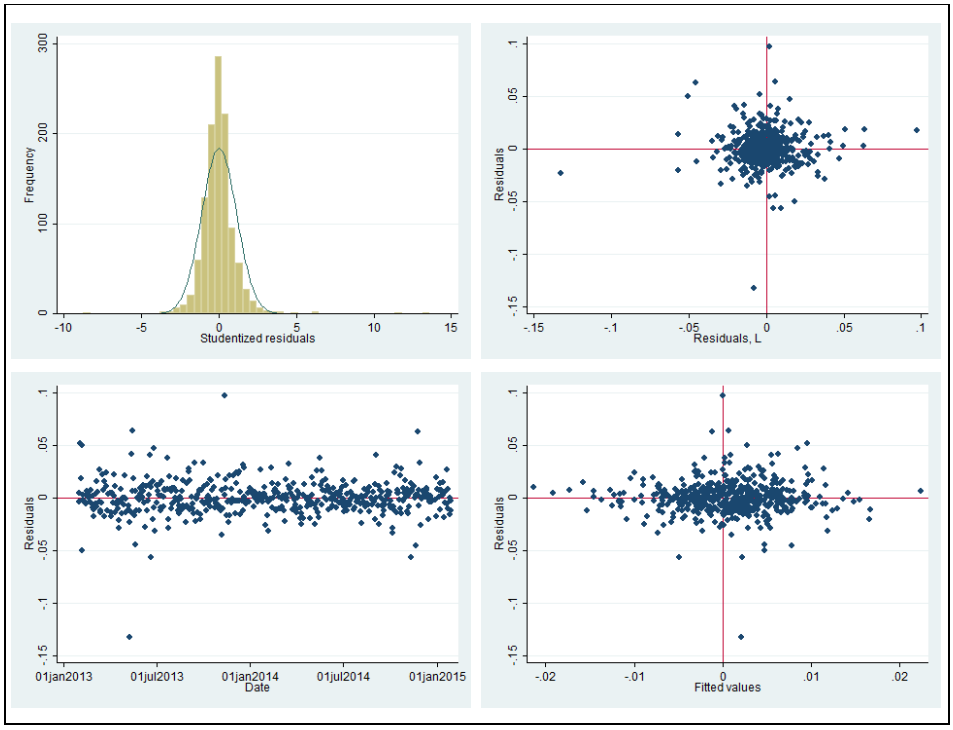


Figure A.9
Sky

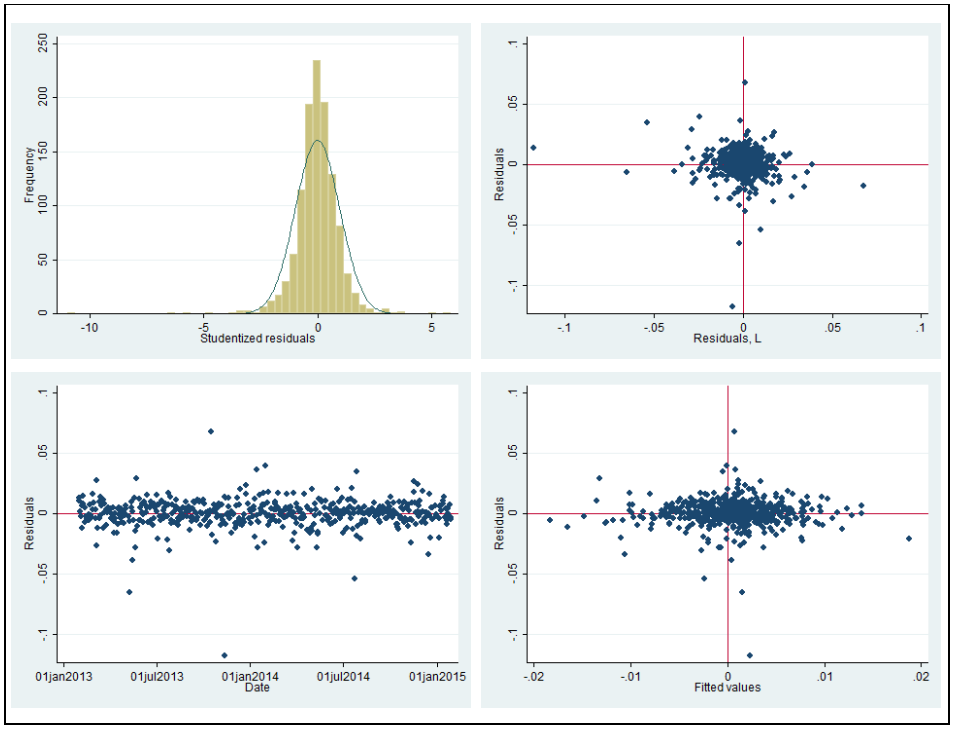
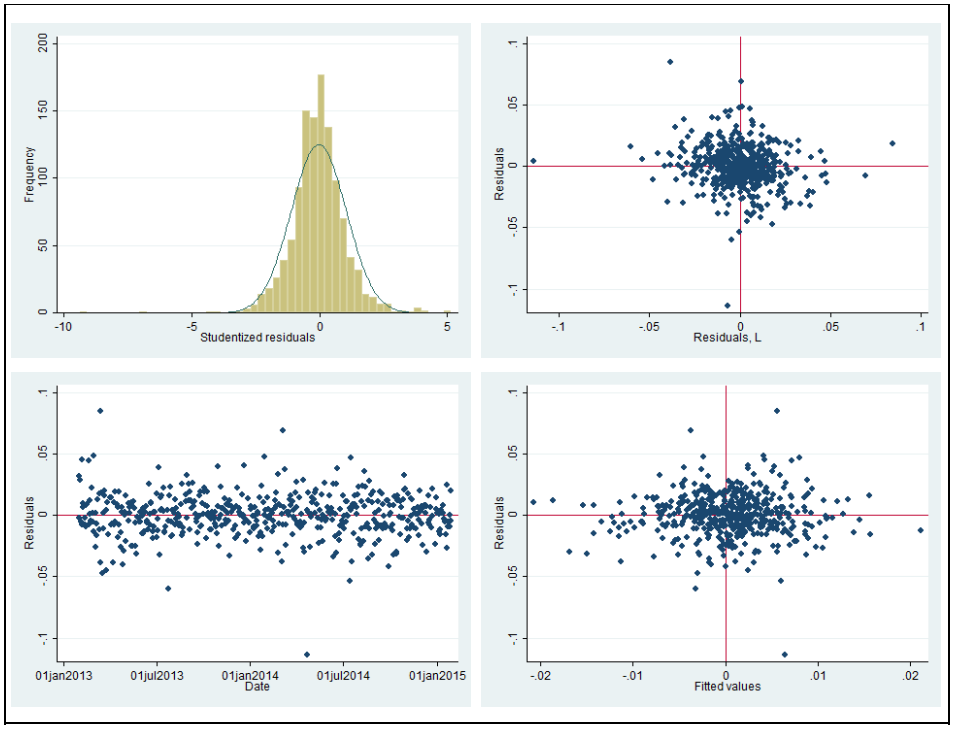


Figure A.10
Colt



Source: NERA Illustration

A.2. Heteroscedasticity and Auto-correlation Tests

We carry out a series of diagnostic tests on the error terms of the regressions to assess whether there is evidence of autocorrelation and/or heteroskedasticity in the error terms.

We perform White and Durbin Watson tests in STATA to detect heteroskedasticity and autocorrelation respectively. We define significance at the 95% confidence levels for both tests. When either heteroskedasticity or autocorrelation is detected, we run and report GLS (Generalized Least Squares) beta estimates, which can address these statistical issues of the estimates of the standard errors.

In Table A.1 and Table A.2 we report White and Durbin Watson test results for the UK telcos and utilities samples.

Table A.1
UK Telcos/Utilities Heteroskedasticity Tests

		FTSE All-Share			FTSE All-World		
		White Stat	P-val	Heterosked a-sticity	White Stat	P-val	Heterosked a-sticity
BT							
	1Y	0.26	0.88	No	0.29	0.87	No
	2Y	0.57	0.75	No	0.27	0.87	No
National Grid							
	1Y	4.03	0.13	No	8.10	0.02	Yes
	2Y	16.50	0.00	Yes	4.48	0.11	No
Severn Trent							
	1Y	14.34	0.00	Yes	11.36	0.00	Yes
	2Y	0.01	0.99	No	0.00	1.00	No
Pennon Group							
	1Y	0.26	0.88	No	0.71	0.70	No
	2Y	0.25	0.88	No	0.80	0.67	No
United Utilities							
	1Y	38.47	0.00	Yes	10.56	0.01	Yes
	2Y	46.95	0.00	Yes	15.76	0.00	Yes
Centrica							
	1Y	4.23	0.12	No	7.21	0.03	Yes
	2Y	3.02	0.22	No	1.89	0.39	No
SSE							
	1Y	0.99	0.61	No	2.18	0.34	No
	2Y	1.15	0.56	No	2.14	0.34	No
Talk Talk							
	1Y	0.66	0.72	No	0.43	0.81	No
	2Y	1.50	0.47	No	0.48	0.79	No
BskyB							
	1Y	0.08	0.96	No	1.46	0.48	No
	2Y	0.32	0.85	No	0.16	0.92	No
Colt							
	1Y	0.98	0.61	No	0.35	0.84	No
	2Y	1.76	0.41	No	0.53	0.77	No

Source: NERA Calculation

Table A.2
UK Telcos/Utilities Autocorrelation Tests

	FTSE All-Share		FTSE All-World	
	Durbin Watson	Serial Correl.?	Durbin Watson	Serial Correl.?
BT				
1Y	2.12	No	2.02	No
2Y	2.22	Yes	2.27	Yes
National Grid				
1Y	2.06	No	2.22	Yes
2Y	1.96	No	2.10	No
Severn Trent				
1Y	2.13	No	2.26	Yes
2Y	2.05	No	2.09	No
Pennon Group				
1Y	2.01	No	2.08	No
2Y	1.99	No	2.03	No
United Utilities				
1Y	2.28	Yes	2.33	Yes
2Y	2.17	Yes	2.23	Yes
Centrica				
1Y	2.00	No	2.16	No
2Y	2.07	No	2.12	No
SSE				
1Y	2.07	No	2.20	No
2Y	2.06	No	2.15	Inconc.
Talk Talk				
1Y	2.14	No	2.15	No
2Y	1.97	No	2.04	No
BskyB				
1Y	2.21	Inconc.	2.19	No
2Y	2.21	Yes	2.23	Yes
Colt				
1Y	2.28	Yes	2.29	Yes
2Y	2.27	Yes	2.26	Yes

Sources: NERA Calculation based on Gujarait and Porter's Basic Econometrics.

Durbin-Watson d statistics critical values (d_L and d_H) are from Stanford University published econometric benchmarks.

For the European comparator regressions against the FTSE All Europe, we diagnose heteroskedasticity for Tele2 and Swisscom, autocorrelation for Telefonica and Mobistar. For European comparator regressions against FTSE All World, we diagnose heteroskedasticity for Tele2 and Swisscom, autocorrelation for Deutsche Telecom and Mobistar.

A.3. Outliers & Robust Regressions

We consider two approaches to assessing the impact from outliers.

One approach is to re-run the OLS regression after elimination of outliers. We detect outliers in our dataset using the Cook's Distance, a commonly used measure of the influence of a data point when performing least squares regression analysis. If Cook's D measure exceeds four divided by the number of observations in the regression, we consider this data point as an outlier. [40]

The alternative is to run robust regressions in STATA, which effectively assign lower weight to data points that have strong influence on the regression line (i.e. outliers).

The table below reports different beta estimates under OLS, OLS with eliminated outliers, and robust regressions for the UK comparators. We note that the differences between these estimates are small.

[40] Cook's D$\equiv \frac{(\hat{\beta}_{(-i)}-\hat{\beta})' \boldsymbol{X}' \boldsymbol{X} (\hat{\beta}_{(-i)}-\hat{\beta})}{\rho s^2}$, where ρ is the number of fitted parameters in the model; s^2 is the mean squared error of the regression model.

See Cook, R. Dennis (March 1979); "Influential Observations in Linear Regression"; Journal of the American Statistical Association

Table A.3
UK Telcos/Utilities Outliers Tests

		FTSE All-Share				FTSE All-World			
		OLS	Robust	Excl. Outliers	No of Outliers	OLS	Robust	Excl. Outliers	No of Outliers
BT									
	1Y	0.85	0.85	0.93	15	0.74	0.77	0.92	17
	2Y	0.98	0.96	0.99	25	0.85	0.82	0.85	22
National Grid									
	1Y	0.71	0.69	0.67	15	0.67	0.62	0.59	14
	2Y	0.69	0.64	0.62	23	0.60	0.58	0.57	21
Severn Trent									
	1Y	0.76	0.82	0.75	15	0.68	0.72	0.72	13
	2Y	0.67	0.64	0.60	21	0.61	0.58	0.60	18
Pennon Group									
	1Y	0.55	0.56	0.58	18	0.45	0.47	0.53	14
	2Y	0.53	0.53	0.51	29	0.49	0.49	0.49	24
United Utilities									
	1Y	0.72	0.78	0.69	14	0.65	0.68	0.71	13
	2Y	0.63	0.66	0.62	30	0.56	0.60	0.64	29
Centrica									
	1Y	0.82	0.83	0.78	17	0.81	0.85	0.76	17
	2Y	0.67	0.68	0.63	27	0.55	0.57	0.54	32
SSE									
	1Y	0.59	0.62	0.61	16	0.54	0.59	0.61	14
	2Y	0.60	0.59	0.58	26	0.51	0.51	0.50	26
Talk Talk									
	1Y	0.67	0.67	0.74	15	0.72	0.70	0.65	14
	2Y	0.75	0.70	0.72	23	0.78	0.67	0.65	27
BskyB									
	1Y	0.72	0.67	0.66	14	0.69	0.55	0.53	10
	2Y	0.64	0.66	0.71	21	0.66	0.55	0.58	15
Colt									
	1Y	0.71	0.75	0.67	9	0.74	0.74	0.79	12
	2Y	0.72	0.67	0.66	23	0.70	0.60	0.57	25

Sources: NERA Calculation

A.4. Dimson Adjustment

We also compute Dimson adjustment to assess the potential impact of non-synchronous trading. We include a one-day lead and a one-day lag term as discussed in section 2.3 above to assess whether the individual stock's return is somewhat correlated with previous or proceeding performance of the market.

The Dimson results shown in Table A.4 below indicate that none of the lead and lag terms are jointly significant, consistent with our findings that the selected comparators for this report are liquid (see section 2.3).

Table A.4
UK Telcos/Utilities Dimson Adjustment Tests

		FTSE All-Share					FTSE All-World				
		OLS	Dimson Adjsted	Significance of lead/lag	Wald P-val	Joint sign.	OLS	Dimson Adjsted	Significance of lead/lag	Wald P-val	Joint sign.
BT											
	1Y	0.83	0.87	Neither lag nor lead	0.95	No	0.67	0.67	Neither lag nor lead	0.12	No
	2Y	1.08	0.89	Neither lag nor lead	0.13	No	0.91	0.68	Only lead	0.05	No
National Grid											
	1Y	0.62	0.55	Neither lag nor lead	0.62	No	0.54	0.55	Neither lag nor lead	0.79	No
	2Y	0.63	0.59	Neither lag nor lead	0.20	No	0.54	0.54	Neither lag nor lead	0.79	No
Severn Trent											
	1Y	0.74	0.64	Neither lag nor lead	0.67	No	0.65	0.61	Neither lag nor lead	0.73	No
	2Y	0.69	0.76	Neither lag nor lead	0.16	No	0.65	0.70	Neither lag nor lead	0.84	No
Pennon Group											
	1Y	0.67	0.49	Neither lag nor lead	0.14	No	0.57	0.43	Neither lag nor lead	0.46	No
	2Y	0.65	0.66	Neither lag nor lead	0.90	No	0.57	0.54	Neither lag nor lead	0.59	No
United Utilities											
	1Y	0.72	0.74	Neither lag nor lead	0.83	No	0.66	0.68	Neither lag nor lead	0.97	No
	2Y	0.67	0.67	Neither lag nor lead	0.55	No	0.66	0.65	Neither lag nor lead	0.68	No
Centrica											
	1Y	0.50	0.51	Neither lag nor lead	1.00	No	0.50	0.48	Neither lag nor lead	0.85	No
	2Y	0.55	0.59	Neither lag nor lead	0.88	No	0.50	0.50	Neither lag nor lead	0.85	No
SSE											
	1Y	0.57	0.34	Neither lag nor lead	0.13	No	0.49	0.34	Neither lag nor lead	0.41	No
	2Y	0.62	0.50	Neither lag nor lead	0.33	No	0.49	0.46	Neither lag nor lead	0.19	No
Talk Talk											
	1Y	0.80	0.75	Neither lag nor lead	0.43	No	0.69	0.90	Neither lag nor lead	0.49	No
	2Y	0.84	0.75	Neither lag nor lead	0.80	No	0.69	0.81	Neither lag nor lead	0.38	No
BskyB											
	1Y	0.65	0.54	Neither lag nor lead	0.61	No	0.54	0.40	Neither lag nor lead	0.48	No
	2Y	0.60	0.52	Neither lag nor lead	0.70	No	0.54	0.47	Neither lag nor lead	0.51	No
Colt											
	1Y	0.79	1.10	Neither lag nor lead	0.42	No	0.70	1.03	Neither lag nor lead	0.39	No
	2Y	0.72	0.90	Neither lag nor lead	0.40	No	0.70	0.78	Neither lag nor lead	0.19	No

Sources: NERA Calculation Note: Results shown with cut-off date 30 October, 2014.

Appendix B. Kalman Filter Technical Details

B.1. Context

Financial markets and their underlying dynamics can experience structural changes over time. In particular, the systematic risk (i.e., non-diversifiable risk) of an asset may change structurally in the event of an acquisition, merger, disinvestment, entry into new line of business etc.

The standard implementation of the CAPM in a regulatory context is to estimate the model using the Ordinary Least Squares (OLS) technique, which solves for a time-invariant systematic risk coefficient (i.e., beta), by implicitly assigning the same weight to each market and stock return pair in the sample. As such, when based on large estimation windows (e.g. 1-year including c. 252 observations, or 2-year including c.504 observations), the OLS approach will internalize changes in the beta very gradually and only when the new information forms large part of the estimation sample.

A more responsive alternative to the 1-year and 2-year OLS beta is to use an OLS based on a narrower estimation window (e.g., a 30-day OLS rolling window). This approach allows for a faster response to new information as each more recent observation (i.e., market and stock return pair) forms a larger part of the estimation sample. However, one of the limitations of this technique is that it also internalizes "noise" (i.e., short-term changes in the beta estimates that are not structural, but rather transitory and purely due to market volatility).

In this report, as a cross-check for the 1-year and 2-year OLS beta estimates thus far used by Ofcom and its consultants, we also used an alternative technique – Kalman Filter – which is a Bayesian approach used for the estimation of time-varying betas. By distinguishing between "structural changes" and "noise", the Kalman Filter procedure has the added advantage of picking up new relevant information very quickly while filtering out the "noise" in the beta estimates.

Below se set out the process used to estimate Kalman filtered equity betas. We derive asset betas using short-term (30-day average) gearing.

B.2. The Kalman Filter Process

The Kalman Filter is a recursive algorithm based on a Bayesian updating procedure, which is used to form estimates of an unobserved variable (in our case "beta") that varies in time. The Kalman Filter procedure updates the beta estimates by using the most recent information it receives from stock and market returns.

Below we set out the Kalman Filter process, which is solved via a maximum likelihood procedure.

The Kalman Filter is built up from two equations: (1) a measurement equation and (2) a transition equation.

- The *measurement equation* relates the unobserved variable (beta) to observed variables (the stock and market returns). For our purposes, the measurement equation corresponds to the well-known CAPM equation, reported as equation 1 below.
- The *transition equation* allows beta to change in time through an autoregressive process. In other words, the transition equation (equation 2 below) relates the beta in time t, to the beta in the previous period, t-1. This allows beta to change in time, as soon as new market data come available, and to reflect a structural change in the beta coefficient of the measurement equation.

$$R_{k,t} = \alpha + \beta_t \cdot R_{m,t} + \varepsilon_t \quad (1)$$

$$\beta_t = T \cdot \beta_{t-1} + \theta_t \quad (2)$$

where T is the state transition matrix and ε_t and θ_t are vectors of serially uncorrelated disturbances with the following distributions: $\varepsilon_t \sim N(0, h_t)$ and $\theta_t \sim N(0, q_t)$,.

The model initiates with some assumptions on the initial parameters and the final stage of the algorithm is solved using a maximum likelihood process to optimise those parameters.

The unknown parameters (α and T) as well as the variances of the noise processes (h_t and q_t) need to be estimated. This is done by maximizing the likelihood function:

$$-\frac{T}{2} ln 2\pi - \frac{1}{2}\sum_{1}^{T} ln\, F_t - \frac{1}{2}\sum_{1}^{T} \frac{v_t' v_t}{F_t}$$

where $v_t = R_{k,t} - \widehat{R_{k,t}}$ and $F_t = Var(v_t)$.

The algorithm procedure is illustrated in Figure B.1 and Figure B.2 below. The Kalman Filter encompasses the following steps:

- Step 1: The filter is initialized by starting the procedure with some initial "guess" parameter values, typically based on an OLS regression of the unknown parameters in the transition equation (i.e., $beta_{t=0}$, T, and the accompanying errors in the transition and measurement equations). Given these initial values, the filter calculates the best *ex ante* beta prediction for the following period, $beta_{t=1,prior}$, by using the transition equation.
- Step 2: Given the calculated *ex ante* value of $beta_{t=1}$, the filter predicts the stock return in time 1 ($\widehat{R_{k,t=1}}$) in the measurement equation by plugging in the expected value of $beta_{t=1,prior}$ and using the known observed value of the stock market return in period 1 ($R_{m,1}$).
- Step 3: Following the observation of the "actual" stock return $R_{k,t=1}$, the model calculates the prediction error (i.e., the difference between the observed and the predicted stock return ($R_{k,t} - \widehat{R_{k,t}}$).
- Step 4: Finally, the model adjusts the forecast for the beta in period 1 ($beta_{t=1,prior}$), by allowing some part of the "prediction error" to feed through in the updated beta ($beta_{t=1,posterior}$). The new beta ($beta_{t=1,posterior}$) is then used in the next step as a $beta_{t=2,prior}$.

The algorithm is then solved recursively via a maximum likelihood function, in order to find those values of the unknown parameters (beta, T, errors) which minimize the prediction error in the stock return.

Figure B.1
Kalman Filter Process – First Iteration

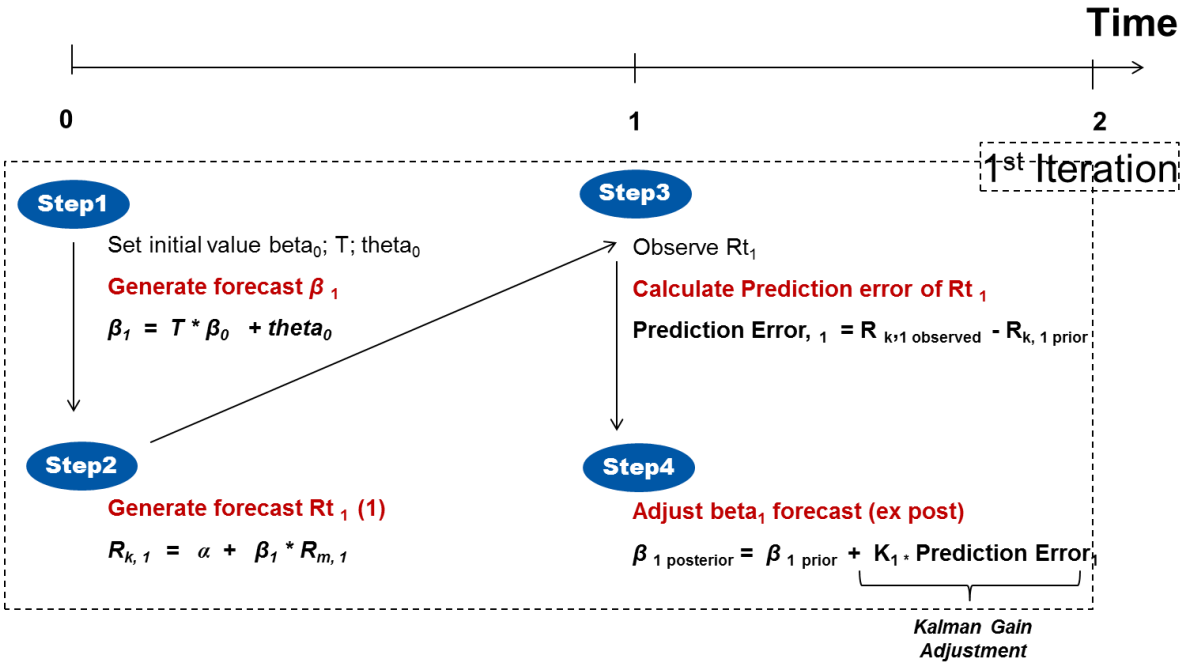
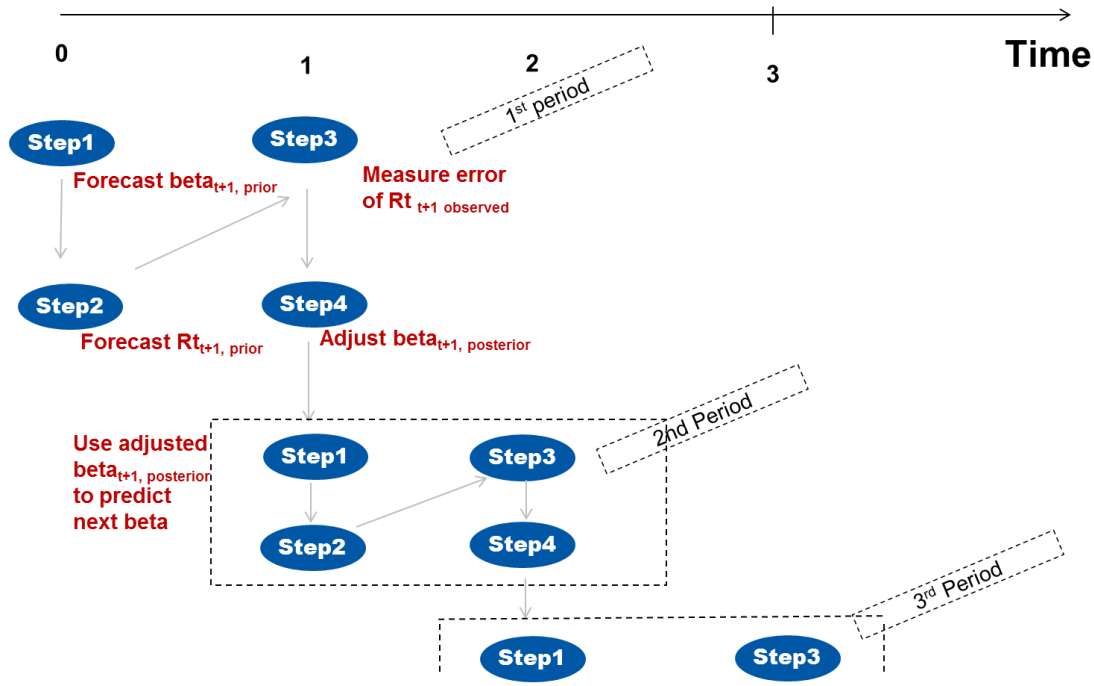


Figure B.2
Kalman Filter - Process



Appendix C. UK and European Telcos Revenue Breakdown

In addition to assessing the beta for the BT Group as a whole and its comparators, we explored the possibility of explaining inter-comparator variation in the betas by assessing the impact from differences in e.g. the share of revenues from business and residential customers However, this type of assessment requires consistent segmental reporting across comparators and across all relevant segments that could explain the differences in risk across the comparators (e.g. customer type, product breakdown etc.).

Table C.1 below summarizes the revenue breakdown information of BT's comparators reported by Bloomberg. As Table C.1 shows, a number of companies only report revenue by product type, i.e. fixed-lines vs mobile revenues, whereas a second set of comparators reports revenues only by customer type, i.e. retail vs. wholesale. Only a very small subset of the comparators segments revenues by both customer and product type. Moreover, the time period over which data is reported on a consistent basis across this subset of comparators is also limited, as shown in Table C.1. The comparable dataset for assessing risk variations on the basis of customer and product type across comparators is therefore limited.

Moreover, a high level assessment of the comparators that report their revenues by customer type (e.g. retail vs wholesale) raises the question of consistency in the customer type sample breakdown. Specifically, none of the comparators distinguished between their local loop access activities (i.e. Openreach type activities) and their other wholesale activities. This limits the usefulness of this segmental breakdown in that the local loop access provision will have inherently different risk profile from other wholesale activities. Additionally, companies' revenue data is not available on a consistent basis over a sufficiently long time window.

Therefore, we conclude that the available sample of segmental reporting by customer and product type is insufficiently well defined to inform robust assessment of inter-company variations in the observed betas.

Table C.1 Breakdown of Revenue of BT Comparators

		Customer type breakdown				Product breakdown	Data Availability	
		Customer Retail	Business Retail	Wholesale	Openreach	Fixed-line vs. Mobile	Customer	Product
By both customer type and product type	Belgacom	Y	Y	Y	N	Y	2007	2011
	Swisscom	Y	Y	Y	N	Y	2007	2005
	KPN	Y	Y	Y	N	Y	2005	2005
	Orange	Y	Y	Y	N	Y	2005	2005 (2007 miss.)
By customer type only	Talk Talk	Y	Y	N	N		2009	
	Sky	Y		Y	N		2005	
	Colt	Y	Y	N	N		2006	
	Time Warner Cable	Y	Y		N		2010	
	Century link	Y	Y	Y	N		2011	
By product type only	Telefonica					Y		2006
	Telenor					Y		2005
	Telecom Italia					Y		2005
	Deutsche Telekom					Y		2004-2010
	Tele2					Y		2005
	Iliad					Y		2010
	Mobistar					Y		2005
	AT&T					Y		2004
	Verizon					Y		2004

Source: NERA Illustration
Note: ("Y" indicates revenue is reported on this category while "N" indicates no data is available)

Appendix D. BT Revenue Breakdown

In the table below we show BT's segment breakdown from 2006 to 2014 in terms of both revenue and EBITDA.

Table D.1
BT Segment Breakdown (%)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
REVENUE									
BT Global Services	36.7%	36.9%	37.0%	40.1%	40.7%	40.1%	40.4%	39.3%	38.5%
BT Retail	41.5%	39.5%	40.7%	38.9%	37.9%	36.1%	35.6%	36.6%	37.7%
BT Wholesale	20.0%	20.1%	17.9%	16.0%	15.4%	16.0%	15.2%	14.3%	13.2%
Openreach	1.6%	3.4%	4.3%	4.7%	5.8%	7.5%	8.4%	9.6%	10.0%
Other	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.3%	0.6%
EBITDA									
BT Global Services	12.7%	13.1%	14.0%	5.0%	8.1%	10.1%	10.3%	10.1%	15.2%
BT Retail	22.2%	24.1%	26.4%	31.8%	32.8%	30.3%	30.2%	31.3%	31.6%
BT Wholesale	26.2%	26.6%	24.3%	24.4%	22.7%	22.4%	19.9%	18.9%	10.0%
Openreach	36.8%	34.2%	33.0%	38.1%	34.8%	36.2%	37.9%	37.4%	42.5%
Other	2.1%	2.0%	2.2%	0.8%	1.6%	1.0%	1.6%	2.2%	0.6%

Note:
BT Retail was split into BT Business and BT Consumer in 2013.However we still show aggregated BT Business and BT Consumer figures under "BT Retail" to improve comparability across years.
EBITDA of Global Services in 2009 was negative in BT's 2009 Annual report. However, in the following years' annual reports, BT adjusted this figure by taking Contract and financial review charges out from operating expense. In the table we show adjusted EBITDA of Global Services in 2009.
Source: BT Annual reports.

NERA
ECONOMIC CONSULTING

NERA Economic Consulting
Marble Arch House, 66 Seymour Street
London W1H 5BT
United Kingdom
Tel: 44 20 7659 8500 Fax: 44 20 7659 8501
www.nera.com

NERA UK Limited, registered in England and Wales, No 3974527
Registered Office: 15 Stratford Place, London W1C 1BE