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# Replication and extension of Henry's beta analysis

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# 1 Executive summary

1. Multinet has commissioned CEG to replicate and extend the beta analysis from Henry<sup>1</sup> (2014) to the most recent period (October 2016). Henry's original analysis was based on the daily closing price, historical market capitalisation and net debt value of a collection of nine stocks ending on 28 June 2013. We have extended Henry's sample to include an additional three year of data up until 7 October 2016.
2. Our replication results are derived by regressing return series we have constructed for the relevant assets/portfolios. These have been compared to, and found to be consistent with, the "Historical Beta" estimates sourced directly from the Bloomberg terminal using "ASX 300 accum"<sup>2</sup> as the benchmarking index. However, while our results are broadly similar to Henry's raw equity betas in his Appendix A there are some slight differences (as detailed below).
3. Our extension of Henry's analysis shows that the average re-levered equity beta has increase materially by 0.23 using the most recent five years of data. This reflects a number of factors including an increase/decrease in the raw equity betas/gearing ratios of the remaining listed stocks (APA, DUE, SKI, AST) and an increase in the weighting of high-beta stocks (e.g., APA) in the value-weighted portfolios.
4. We note that the measured increase in beta is consistent with the observation from our DBP report<sup>3</sup> which identifies a structural break in the average rolling beta series at 2014/15.
5. Table 1 below summarises the result from our extension to Henry's individual stock beta analysis. This table is directly compared with Table 3-35 from the United Energy Electricity distribution determination final decision in Victoria. Evidence suggests that beta has increased around 0.10 or more since the end of Henry's sampling period.

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<sup>1</sup> Olan T. Henry, *Estimating  $\beta$ : An update*, April 2014

<sup>2</sup> The same benchmarking index used by Henry (2014).

<sup>3</sup> CEG, *Estimating beta to be used in the Sharpe-Lintner CAPM*, February 2016, Section 5



**Table 1: Summary of extension results for re-levered OLS weekly individual beta estimates**

	<b>Longest available period</b>	<b>Longest available period (excl. tech boom and GFC)</b>	<b>Last five years</b>
Henry original results	0.52	0.56	0.46
CEG extension results	0.60	0.66	0.69
<b>Change</b>	<b>0.08</b>	<b>0.10</b>	<b>0.23</b>

*Bloomberg data, CEG analysis*

6. It should be noted that Henry's average "last five years" beta estimates includes six firms (APA, DUE, DNV, HDF, SKI and AST), among which ENV and HDF were delisted in 2013 and 2014, respectively. Including these two stocks at the time of our estimates (October 2016) would result in a considerably smaller number of observations than other stocks (153 for ENV and 59 for HDF as compared with 261 for others). Therefore, our "last five years" beta estimates is only averaged across the four currently listed firms as in Table 13.
7. Table 2 below shows the measured betas for the six portfolios as outlined in section 4.1 for the two sampling periods. In each of portfolios 1 to 5 there is at least one, and generally more, firms that do not have data up to October 2016. Consequently, the change in beta estimates for these portfolios is muted (given that some firms have the same (or similar) beta simply because there is no (little) additional data). Portfolios 1 and 5 are the only Henry portfolios comprised solely of firms with additional data (APA and ENV in portfolio 1 and SKI, APA, ENV, DUE, AST in Portfolio 5). Portfolio 6 is added by CEG and is the same as Portfolio 5 but excludes Envestra which only has one year of additional data. Compared with Table 3-36 from the United Energy distribution determination final decision, and focusing on portfolio 5, Table 2 suggests that average portfolio betas has since then increased by around 0.15 or more.

**Table 2: Summary of extension results for re-levered OLS weekly portfolio beta estimates**

	P1	P2	P3	P4	P5	P6
<b>Equal weighted</b>						
Longest available period	0.55	0.52	0.52	0.53	0.54	0.55
Increase vs Henry	0.09	0.00	0.01	0.05	0.15	N/A
Longest available period (excl. tech boom and GFC)	0.61	0.52	0.58	0.60	0.63	0.65
Increase vs Henry	0.11	0.00	0.03	0.07	0.17	N/A
<b>Value weighted</b>						
Longest available period	0.63	0.70	0.45	0.47	0.56	0.57
Increase vs Henry	0.13	0.00	0.01	0.05	0.17	N/A
Longest available period (excl. tech boom and GFC)	0.69	0.70	0.54	0.57	0.66	0.68
Increase vs Henry	0.16	0.00	0.02	0.06	0.19	N/A

*Bloomberg data, CEG analysis*

8. Table 3 shows the most recent 5 year beta estimates for portfolios and compares it against the 5 years leading up to Henry's end date. The result shows that the re-levered equity beta has increased by 0.19 to 0.31 between the two periods.

**Table 3: Summary of extension of portfolio recent 5 year beta estimates**

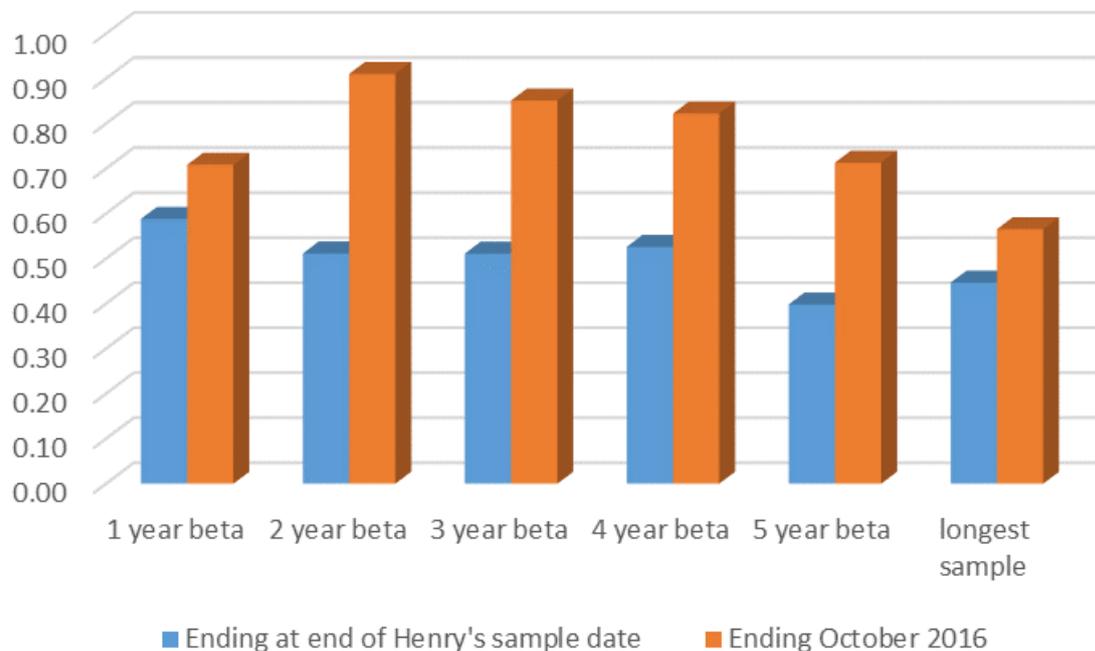
	P1	P5	P6
<b>Equal weighted</b>			
Most Recent 5 Years	0.75	0.67	0.69
Increase vs Henry End Date	0.25	0.27	0.29
Most Recent 5 Years (exc. Tech Boom and GFC)	0.75	0.67	0.69
Increase vs Henry End Date	0.20	0.20	0.22
<b>Value weighted</b>			
Most Recent 5 Years	0.78	0.70	0.71
Increase vs Henry End Date	0.24	0.30	0.31
Most Recent 5 Years (exc. Tech Boom and GFC)	0.78	0.70	0.71
Increase vs Henry End Date	0.19	0.22	0.22

*Bloomberg data, CEG analysis*

9. Irrespective of the length of the sample period, the re-levered equity betas for samples ending in October 2016 are materially higher compared to the sample ending on Henry's sample end date. This is illustrated in Figure 1. The analysis is

applied to portfolio 6<sup>4</sup> because it is the only portfolio for which all of the constituents have data to October 2016.

**Figure 1: Effect of sample size (value weighted portfolio)**



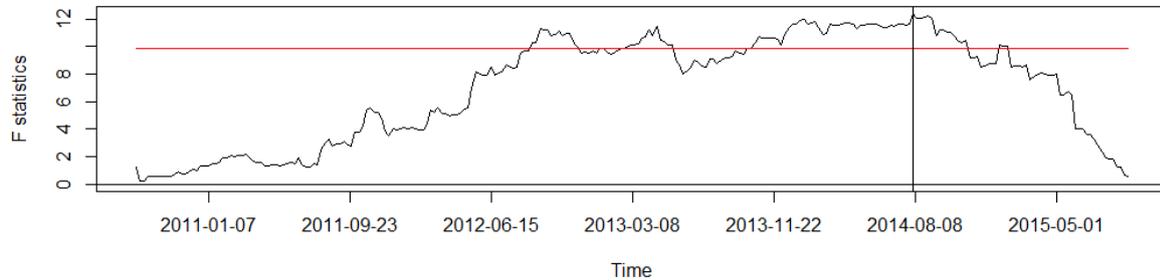
*Bloomberg Data, CEG analysis*

10. Given the observed increase in asset beta (and, therefore, re-levered equity beta) when the sample period is extended, a structural break test is conducted to determine whether the change in asset beta represents a statistically significant structural break.
11. When applied to portfolio 6<sup>5</sup>, the Quandt-Andrews structural break test identifies a break within the GFC and, when run on post GFC data, identifies another break in August 2014. Figure 2 shows the result with the test statistics lying above the 10% p-value threshold during 2014, thus rejecting stability across the whole sample. The point with the highest likelihood of structural break occurs in August 2014.

<sup>4</sup> Portfolio 6 is constructed using APA AU Equity, DUE AU Equity, AST AU Equity, SKI AU Equity.

<sup>5</sup> Portfolio 6 is constructed using APA AU Equity, DUE AU Equity, AST AU Equity, SKI AU Equity.

**Figure 2: F-statistics for value weighted portfolio (post GFC)**



Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test

12. Comparison of re-levered equity beta before and after the 2014 August breakpoint is shown in Table 4. The re-levered equity beta of the equal (value) weighted portfolio 6 has increased by 0.37 (0.38) between the pre and post structural break sample periods. The best estimate of the re-levered equity beta is at least 0.88 after the 2014 August breakpoint and 0.7 over the last 5 years.

**Table 4: Re-levered equity beta before and after August 2014 (portfolio6)**

	Equal weighted portfolio	Value weighted portfolio
Estimated Re-Levered Equity Beta for Whole Sample	0.58	0.60
Estimated Re-Levered Equity Beta prior to breakpoint	0.50	0.53
Estimated Re-Levered Equity Beta after breakpoint	0.88	0.90
<b>Difference before and after breakpoint</b>	<b>0.38</b>	<b>0.37</b>

*Bloomberg Data, CEG analysis*

13. The 0.88 and 0.90 re-levered betas post August 2014 are based on a little over 2 years of data. However, as can be seen from Figure 2 above, there are high F-statistics from late 2012 to late 2014 - suggesting that discernible differences in asset beta began presenting in the data up-to two years prior to the maximum F-statistic observed for August 2014. This suggests that, when attempting to arrive at a post-break asset beta estimate it is reasonable to also have regard to 3 and 4 year beta estimates. As per Table 16 and Table 17 in the body of this report these range from 0.79 to 0.85. This support a post-structural break estimate for the re-levered equity beta of 0.8 (based on 3-4 year betas) to 0.9 (based on the identified date of the highest F-statistic).

## 2 Introduction

14. I have been asked by Multinet to provide a report on the replication and extension of the beta analysis from Henry<sup>6</sup> (2014) to the most recent period (June 2015).
15. The remainder of this report has the following structure:
  - Section 3 replicates and extend Henry's analysis on individual firm betas;
  - Section 4 replicates and extend Henry's portfolio analysis;
  - Section 5 discusses the most recent 5 and 1 year estimates of the equity beta
  - Section 6 discusses the differences in beta ending mid 2013 compared to October 2016.
  - Section 7 discusses the analysis of a structural break in asset beta
16. I acknowledge that I have read, understood and complied with the Federal Court of Australia's Practice Note CM 7, "Expert Witnesses in Proceedings in the Federal Court of Australia". I have made all inquiries that I believe are desirable and appropriate to answer the questions put to me. No matters of significance that I regard as relevant have to my knowledge been withheld.
17. I have been assisted in the preparation of this report by Ker Zhang in CEG's Sydney office. However, the opinions set out in this report are my own.



Thomas Nicholas Hird

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<sup>6</sup> Olan T. Henry, *Estimating  $\beta$ : An update*, April 2014

## 3 Individual stock beta – longest available period

### 3.1 Sampling period

18. Table 5 below summarises our extended sampling period for Henry’s (weekly) beta analysis. It can be seen that for the four stocks that are still listed (APA, DUE, SKI and AST), our analysis has included an additional 171 weekly observations while ENV there was only 63 new data points as it was delisted in October 2014.

**Table 5: Extended sampling period of Henry’s analysis**

<b>Bloomberg ticker</b>	<b>Henry start date</b>	<b>Henry end date</b>	<b>Henry # of observations</b>	<b>CEG extended end date</b>	<b>CEG # of observations</b>	<b>Difference in # of observations</b>
AAN AU Equity	20/10/2000	28/06/2013	356		356	0
AGL AU Equity	29/5/1992	6/10/2006	749		749	0
APA AU Equity	16/6/2000	28/06/2013	680	7/10/2016	851	171
DUE AU Equity	13/8/2004	28/06/2013	463	7/10/2016	634	171
ENV AU Equity	29/8/1997	28/06/2013	826	12/9/2014	889	63
Gas AU Equity	21/12/2001	10/11/2006	255		255	0
HDF AU Equity	17/12/2004	23/11/2012	414		414	0
SKI AU Equity	02/03/2007	28/06/2013	330	7/10/2016	501	171
AST AU Equity	16/12/2005	28/06/2013	393	7/10/2016	564	171

*Bloomberg Data, CEG analysis*

19. It should be noted that the following stock ticker changes have occurred: AGL AU Equity was renamed from AGK AU Equity for AGL energy limited; and AST AU Equity is renamed from SPN AU Equity for SP AusNet.

### 3.2 CEG replication of Henry’s Table 2 and A1

20. Henry’s Table 2 shows the de-levered/re-levered beta and Table A1 in his appendix shows the corresponding raw estimates of equity beta. In replicating these tables, we sourced historical closing price, market capitalisation and net debt for each of the nine firms in the sample. We then calculate various beta measures.

21. The replication results are shown in Table 6 below. Consistent with Henry's notation,  $w$  stands for the re-levering factor<sup>7</sup> and gearing is calculated based on the average market capitalisation and net debt during the sampling period.

**Table 6: CEG replication of weekly individual beta estimates (longest available sample up to Henry's end date using weekly data)**

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity (CEG Replication)	Re-levered equity (Henry actual)
AAN AU Equity	0.57	0.35	1.55	0.38	0.89	0.88
AGL AU Equity	0.39	0.27	1.73	0.31	0.67	0.68
APA AU Equity	0.54	0.24	1.12	0.55	0.61	0.59
DUE AU Equity	0.48	0.12	0.62	0.75	0.30	0.28
ENV AU Equity	0.43	0.12	0.69	0.72	0.30	0.30
Gas AU Equity	0.35	0.13	0.90	0.64	0.31	0.31
HDF AU Equity	0.74	0.44	1.47	0.41	1.09	1.03
SKI AU Equity	0.38	0.21	1.37	0.45	0.52	0.33
AST AU Equity	0.29	0.12	1.00	0.60	0.29	0.29
<b>Average</b>	<b>0.46</b>	<b>0.22</b>	<b>1.16</b>	<b>0.54</b>	<b>0.55</b>	<b>0.52</b>

*Bloomberg data, CEG analysis*

22. The last two columns in Table 6 compares our replication and Henry's actual figure side-by-side for each individual stock. We note that our estimates are different to Henry's, most notably for SKI, although the average figure is similar.
23. To examine robustness of our estimates (and the source of the discrepancy with Henry's estimates), we have compared our estimates with the "Raw beta" from Bloomberg's "Historical Beta" field and found that our estimates are consistent with the figures from Bloomberg based on Henry's sample and benchmark index (ASX 300 accum); while Henry's raw beta from his Table A1 is slightly different.
24. We note that most of the difference in re-levered equity is due to differences in gearing estimates. For example, for SKI our gearing figure is 45.4% while Henry's is 66%. Similarly, our gearing estimate for HDF is materially lower (40% vs 48%). We have very similar gearing estimates for the other firms.
25. Given our result is consistent with Bloomberg's figures and the difference in average is minimal, we have used our replication as the reference point to identify the impact of extending the sample period to October 2016 in the following sections.

<sup>7</sup>  $W = (1 - \text{gearing}) / 1 - 0.6$

### 3.3 CEG extension of Henry's Table 2 (as of October 2016)

26. Table 7 below show our extension of Henry's Table 2. The red column corresponds our replication of Henry's figure in Table 4 while the blue column shows the estimated (re-levered) equity beta based on the extended sample; the last column calculates the difference. Note that the extended estimate for Envestra only uses data up to its delisting in September 2014. Unsurprisingly, its change in beta is the smallest.

**Table 7: CEG extension of weekly individual beta estimates (longest available sample up to October 2016 using weekly data)**

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (CEG replication)	Re-levered equity beta (CEG extension)	Change
AAN AU Equity	0.57	0.35	1.55	0.38	0.89	NA	NA
AGL AU Equity	0.39	0.27	1.73	0.31	0.67	NA	NA
APA AU Equity	0.57	0.29	1.25	0.50	0.61	0.71	0.11
DUE AU Equity	0.46	0.14	0.76	0.70	0.30	0.35	0.05
ENV AU Equity	0.43	0.13	0.75	0.70	0.30	0.33	0.03
Gas AU Equity	0.35	0.13	0.90	0.64	0.31	NA	NA
HDF AU Equity	0.74	0.44	1.47	0.41	1.09	NA	NA
SKI AU Equity	0.42	0.27	1.57	0.37	0.52	0.66	0.14
AST AU Equity	0.37	0.16	1.04	0.58	0.29	0.39	0.10
							<b>0.05-0.14*</b>

Bloomberg data, CEG analysis. \* The bottom end of this range shows the smallest change in beta for one of the four firms with data all the way to October 2016 (DUE). The top end of this range is the largest change in beta amongst these firms (for SKI).

27. The additional data has increased measured equity betas for all five firms with additional data. If we focus only on the firms for which data is available to October 2016, our result suggests that the average re-levered equity beta has increased by 0.05 to 0.14 (average increase of 0.10).

## 4 Portfolio beta – longest available period

### 4.1 Portfolio construction

28. Following the instructions from the AER, Henry (2014) constructed five portfolios each with different constituent stocks and sampling period<sup>8</sup>. In addition to these five portfolios, our portfolio analysis included a new portfolio consists of the remaining four listed stocks (APA, DUE, SKI and AST) as ENV was delisted in 2014.
29. Table 8 below summarise the constituent stocks and sampling periods for our portfolio analysis. It can be seen P2-P4 are not affected by the extension as they include stocks that were delisted before Henry's end date in 2013

**Table 8: Portfolio construction and sampling period**

Portfolio	Constituent stocks	Henry start date	Henry end date	Henry # of observations	CEG end date	CEG # of observations
P1	APA, ENV	16/06/2000	28/06/2013	680	7/10/2016	797 <sup>9</sup>
P2	AAN, AGL, APA, ENV, GAS	21/12/2001	06/10/2006	250	06/10/2006	250
P3	APA, DUE, ENV, HDF, AST	16/12/2005	23/11/2012	362	23/11/2012	362
P4	APA, DUE, ENV, HDF, SKI, AST	02/03/2007	23/11/2012	299	23/11/2012	299
P5	APA, DUE, ENV, SKI, AST	02/03/2007	28/06/2013	330	7/10/2016	479 <sup>10</sup>
P6	APA, DUE, SKI, AST	02/03/2007	28/06/2013	330	7/10/2016	501

*Bloomberg data, CEG analysis*

<sup>8</sup> Olan T. Henry, *Estimating  $\beta$ : An update*, April 2014, P. 35

<sup>9</sup> Average number of observations is reported, since ENV was delisted in 2014.

<sup>10</sup> Average number of observations is reported, since ENV was delisted in 2014.

## 4.2 CEG replication and extension of Henry's Table 14 and A4

30. Henry's Table 14 and A4 document the beta estimates for five *equal-weighted* portfolio consists of different stocks and sampling periods. This section attempts to replicate his result.
31. As noted before, our beta estimates are slightly different from Henry's results. Table 9 below shows our replication result side-by-side with Henry's estimates for the equal-weighted portfolios. Note that Henry has only five portfolios while we have six. The difference in average (re-levered) equity beta is around 0.02.

**Table 9: CEG replication of weekly equal weighted portfolio beta (longest available sample up to Henry's end date using weekly data)**

Portfolio	Equity beta	Asset beta	W	gearing	Re-levered equity (CEG Replication)	Re-levered equity (Henry)
p1	0.51	0.18	0.91	0.64	0.46	0.46
p2	0.42	0.21	1.25	0.50	0.52	0.52
p3	0.53	0.21	0.97	0.61	0.52	0.50
p4	0.51	0.21	1.02	0.59	0.53	0.48
p5	0.46	0.18	0.97	0.61	0.45	0.39
p6	0.45	0.18	1.02	0.59	0.45	
<b>Average</b> <sup>11</sup>	<b>0.49</b>	<b>0.20</b>	<b>1.03</b>	<b>0.59</b>	<b>0.49</b>	<b>0.47</b>

*Bloomberg data, CEG analysis*

32. Consistent with the approach adopted in the previous section, we will use our replication as the reference to compare with the results from the extended sample in the following sections.
33. Table 10 below shows our extension of Henry's Table 16. The red column is our replication of Henry's figure while the blue column corresponds to the estimated (re-levered) equity beta based on the extended sample.

<sup>11</sup> Portfolio 6 not included in average.

**Table 10: CEG extension of weekly equal-weighted portfolio beta (longest available sample up to October 2016 using weekly data)**

Portfolio	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (CEG replication)	Re-levered equity beta (CEG extension)	Change
p1	0.54	0.22	1.01	0.60	0.46	0.55	0.09
p2	0.42	0.21	1.25	0.50	0.52	NA	NA
p3	0.53	0.21	0.97	0.61	0.52	NA	NA
p4	0.51	0.21	1.02	0.59	0.53	NA	NA
p5	0.49	0.22	1.10	0.56	0.45	0.54	0.09
p6	0.48	0.22	1.16	0.54	0.45	0.55	0.10
							0.09-0.10*

*Bloomberg data, CEG analysis.*

34. Consistent with that from Table 7, Table 10 shows that the average beta has increased by around 0.09 since the end of Henry’s sample if we focus only on the portfolios for which additional data is available.

### 4.3 CEG replication and extension of Henry’s Table 16 and A6

35. Henry’s Table 16 and A6 present the beta estimates for five *value*-weighted portfolio consists of different stocks and sampling periods. To replicate his result we have to first calculate the weight for each constituent stock according to their average market capitalisation for the sampling period.
36. Figure 3 below shows the calculated weights for each of the stocks in their corresponding portfolios based on the “Hist\_mkt\_cap” field from Bloomberg. We note that these weighting are close, albeit not identical, to the weights used by Henry<sup>12</sup> (2014).

<sup>12</sup> Olan T. Henry, *Estimating  $\beta$ : An update*, April 2014, Annex A.

**Figure 3: CEG replication of weights in value weighted portfolios**



*Bloomberg data, CEG analysis*

37. Table 11 below shows our replication result side-by-side with Henry’s estimates for the value-weighted portfolios. We note that the difference between our replication and Henry’s actual figure is 0.02, on average.

**Table 11: CEG replication of weekly value-weighted portfolio beta (longest available sample up to Henry's end date using weekly data)**

Portfolio	Equity beta	Asset beta	W	Gearing	Re-levered equity	Re-levered equity (Henry)
p1	0.52	0.20	0.97	0.61	0.50	0.50
p2	0.45	0.28	1.58	0.37	0.70	0.70
p3	0.48	0.18	0.94	0.62	0.45	0.44
p4	0.47	0.19	1.00	0.60	0.47	0.42
p5	0.45	0.18	1.00	0.60	0.44	0.39
p6	0.44	0.18	1.02	0.59	0.45	
<b>Average</b> 13	<b>0.47</b>	<b>0.21</b>	<b>1.10</b>	<b>0.56</b>	<b>0.51</b>	<b>0.49</b>

*Bloomberg data, CEG analysis*

38. Following Henry's approach, we have calculated the portfolio weights to be applied in the extended sampling periods. This is shown in Figure 4 below. Compared with Figure 3, Figure 4, shows that the average market capitalisation for APA has increased relative to other stocks. As a consequence, its weight in portfolio p1, p5 and p6 has been lifted.

<sup>13</sup> Portfolio 6 not included

**Figure 4: CEG extension of weights in value-weighted portfolios**



*Bloomberg data, CEG analysis*

39. Table 12 below shows our extension to Henry's Table 16. The red column corresponds to our replication of Henry's figure while the blue column shows the estimated (re-levered) equity beta based on the extended sample.

**Table 12: CEG extension of weekly value-weighted portfolio beta (longest available sample up to October 2016 using weekly data)**

Portfolio	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (CEG replication)	Re-levered equity beta (CEG extension)	Change
p1	0.56	0.25	1.13	0.55	0.50	0.63	0.12
p2	0.45	0.28	1.58	0.37	0.70	NA	NA
p3	0.47	0.18	0.94	0.62	0.45	NA	NA
p4	0.46	0.19	1.00	0.60	0.47	NA	NA
p5	0.49	0.22	1.13	0.55	0.44	0.56	0.12
p6	0.49	0.23	1.15	0.54	0.45	0.57	0.12
							<b>0.12</b>

*Bloomberg data, CEG analysis.*

40. Consistent with results from Table 7 and Table 10, Table 12 shows that the de-levered/re-levered equity beta has increase by 0.12 on average if we focus only on the portfolios for which additional data is available.

## 5 Most recent beta

### 5.1 Last five years beta (Henry's Table 4 and A3)

41. Henry's Table 4 and A3 shows his estimates of the weekly beta for the "last five year". To draw a comparison, we have also estimated the re-levered equity beta for the most recent 5 years. Results are shown in Table 13 below<sup>14</sup>.

**Table 13: CEG extension of weekly individual beta estimates for the most recent 5 years**

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (Henry actual)	Re-levered equity beta (CEG extension)	Change
APA AU Equity	0.59	0.32	1.36	0.46	0.54	0.81	0.27
DUE AU Equity	0.31	0.12	0.93	0.63	0.24	0.28	0.04
SKI AU Equity	0.47	0.34	1.83	0.27	0.30	0.86	0.56
AST AU Equity	0.74	0.32	1.08	0.57	0.27	0.81	0.54
<b>Average</b>	<b>0.53</b>	<b>0.28</b>	<b>1.30</b>	<b>0.48</b>	<b>0.34</b>	<b>0.69</b>	<b>0.35</b>

*Bloomberg data, CEG analysis*

42. The 5-year weekly beta for all four stocks has increased, with significant increases for three of the four stocks, and a doubling in the average beta. We note that the rise in beta is much more apparent when examining the last 5 years compared to estimates using the "longest possible sample". This is because of the relatively small weight additional data receives in the longer historical estimates.
43. We also investigate the portfolio re-levered equity beta for the last 5 years and compare it to the last 5 years ending on Henry's end date. Given that portfolio 2 ended in 2006, there are no observations for the current last 5 years and it is ignored. Similarly, both portfolio 3 and portfolio 4 ended in 2012, resulting in only 59 observations. Therefore these two portfolios are also dropped from the analysis. This leaves only portfolio 1, portfolio 5 and portfolio 6 for analysis.
44. Table 14 and Table 15 presents the result for equal weighted and value weighted portfolios respectively. Comparing the most recent 5 years ending on Henry's end date and the most recent 5 years ending in October 2016, the re-levered equity beta has increased by 0.24-0.31.

<sup>14</sup> ENV and HDF are not included because they were delisted thus had considerably less amount of observations.

**Table 14: CEG extension of weekly portfolio (equal weighted) beta estimates for the most recent 5 years**

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (Henry end date replicated)	Re-levered equity beta (CEG extension)	Change
P1	0.61	0.30	1.22	0.51	0.49	0.75	0.25
P5	0.53	0.27	1.26	0.50	0.40	0.67	0.27
P6	0.53	0.27	1.30	0.48	0.40	0.69	0.29
<b>Average</b>	<b>0.56</b>	<b>0.28</b>	<b>1.26</b>	<b>0.50</b>	<b>0.43</b>	<b>0.70</b>	<b>0.27</b>

*Bloomberg data, CEG analysis*

**Table 15: CEG extension of weekly portfolio (value weighted) beta estimates for the most recent 5 years**

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (Henry end date replicated)	Re-levered equity beta (CEG extension)	Change
P1	0.60	0.31	1.30	0.48	0.54	0.78	0.24
P5	0.56	0.28	1.26	0.50	0.40	0.70	0.30
P6	0.56	0.29	1.28	0.49	0.40	0.71	0.31
<b>Average</b>	<b>0.57</b>	<b>0.29</b>	<b>1.28</b>	<b>0.49</b>	<b>0.45</b>	<b>0.73</b>	<b>0.29</b>

*Bloomberg data, CEG analysis*

## 6 Betas measured to mid 2013 vs October 2016

45. Table 16 and Table 17 show the estimated weekly betas for Henry's portfolio 6 (noting that portfolio 6 is the only portfolio for which all of the constituents have data to October 2016). Each table has 12 re-levered beta estimates associated with 6 different measurement periods (from 1 year to the longest time period available) each of which ends on one of two dates (either 7 October 2016 or 28 June 2013). Table 16 shows the result for equal weighted portfolio and Table 17 shows the result for value weighted portfolio.
46. Henry's report only investigated the longest sample and the 5 year sample size and the result shows that there is a small variation (5 year estimate is 0.05 higher than the longest measurement period). However, with an October 2016 end date, the 5 year re-levered betas is 0.14 above the longest time period re-levered beta. Moreover, the longest time period beta is also materially higher (0.55-0.57 ending in October 2016 vs 0.45 ending in June 2013).

**Table 16: Impact of sample length for different end dates (equal weighted)**

Length of sample	Ending at end of Henry's sample date				Ending October 2016			
	Equity beta	Gearing	Asset beta	Re-levered equity beta	Equity beta	Gearing	Asset beta	Re-levered equity beta
1 year	0.46	0.50	0.23	0.57	0.51	0.46	0.28	0.69
2 year	0.40	0.53	0.19	0.48	0.64	0.45	0.35	0.88
3 year	0.43	0.56	0.19	0.48	0.62	0.46	0.33	0.83
4 year	0.48	0.58	0.20	0.50	0.60	0.47	0.32	0.79
5 year	0.39	0.59	0.16	0.40	0.53	0.48	0.27	0.69
Longest sample	0.44	0.59	0.18	0.45	0.48	0.53	0.22	0.55

*Bloomberg Data, CEG analysis*

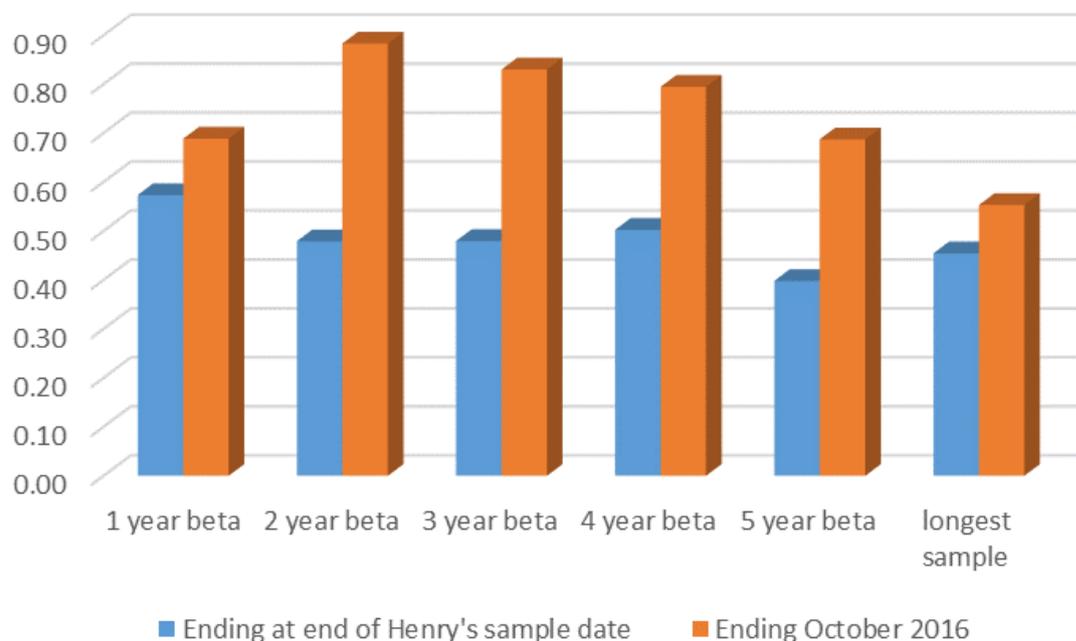
**Table 17: Impact of sample length for different end dates (value weighted)**

Length of sample	Ending at end of Henry's sample date				Ending October 2016			
	Equity beta	Gearing	Asset beta	Re-levered equity beta	Equity beta	Gearing	Asset beta	Re-levered equity beta
1 year	0.48	0.51	0.24	0.59	0.54	0.48	0.28	0.71
2 year	0.43	0.53	0.20	0.51	0.68	0.47	0.36	0.91
3 year	0.46	0.56	0.20	0.51	0.65	0.48	0.34	0.85
4 year	0.50	0.58	0.21	0.53	0.63	0.48	0.33	0.82
5 year	0.39	0.59	0.16	0.40	0.56	0.49	0.29	0.71
Longest sample	0.44	0.59	0.18	0.45	0.49	0.54	0.23	0.57

*Bloomberg Data, CEG analysis*

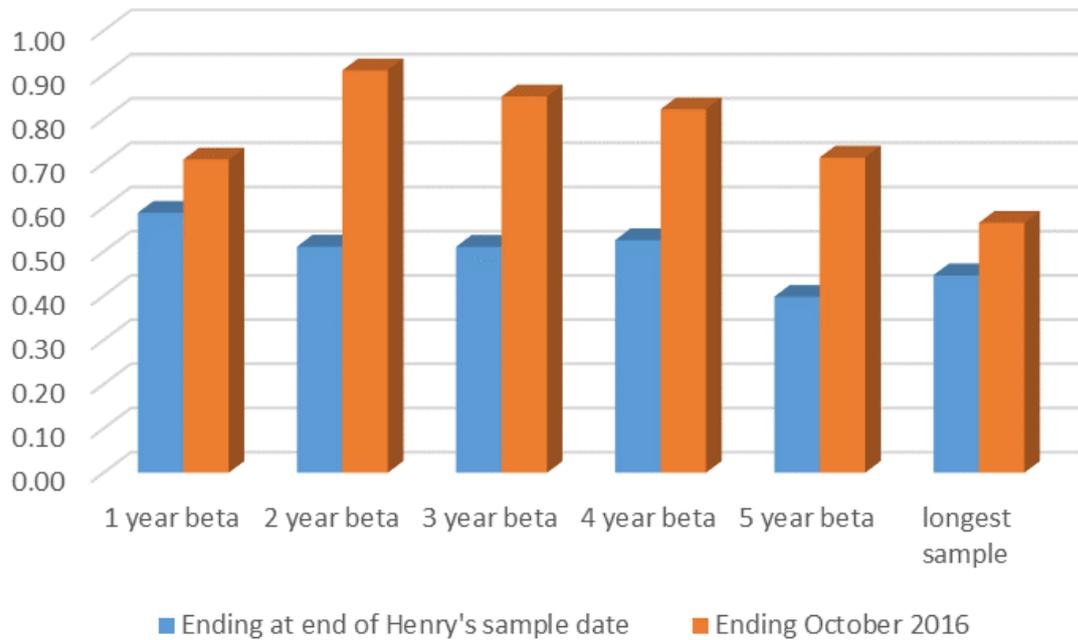
47. The re-levered equity beta over different measurement periods is illustrated graphically in Figure 5 and Figure 6. The betas measured to October 2016 are all materially higher than those measured to Henry's end date.

**Figure 5: Effect of sample size (equal weighted portfolio)**



*Bloomberg Data, CEG analysis*

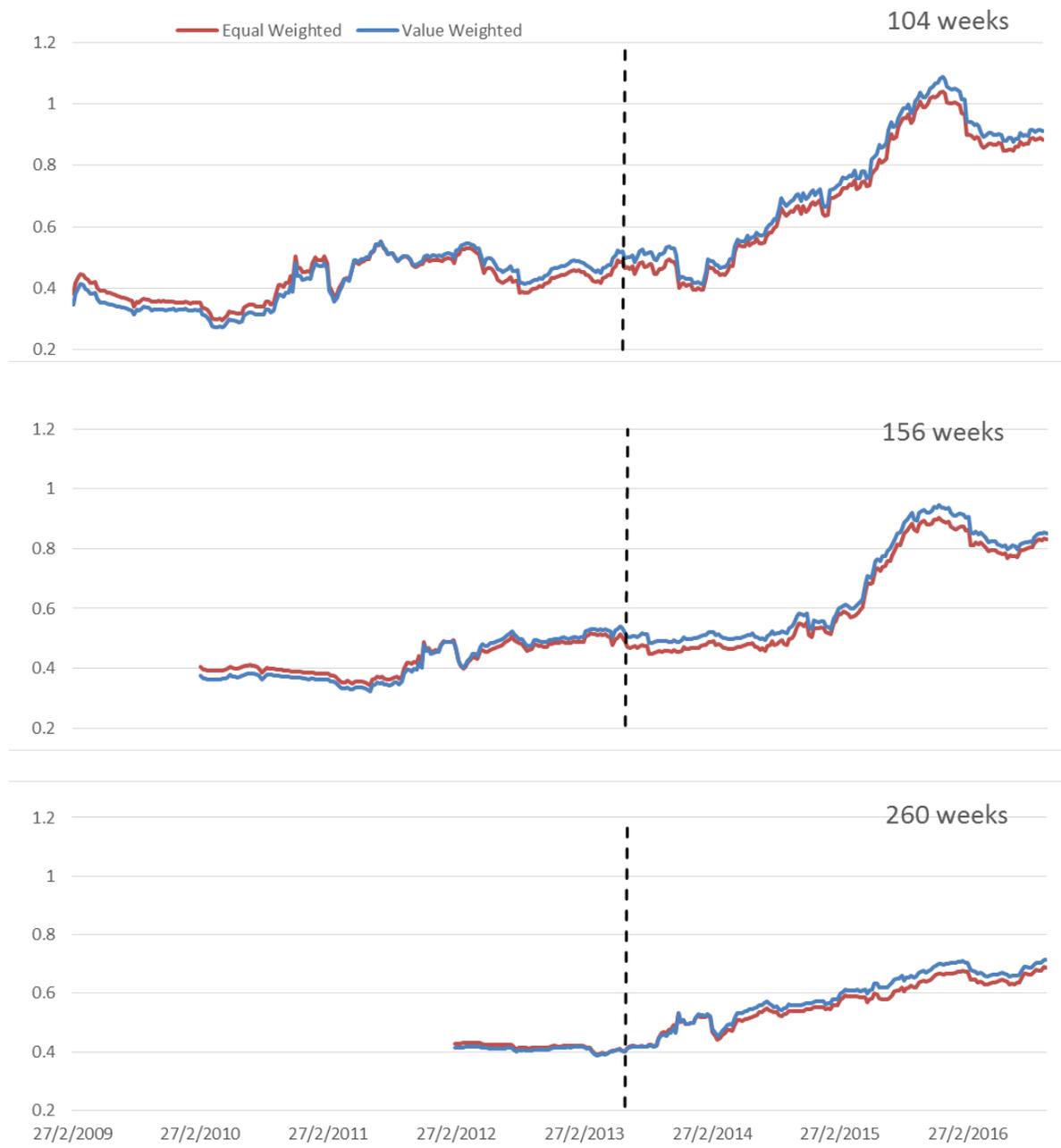
**Figure 6: Effect of sample size (value weighted portfolio)**



*Bloomberg Data, CEG analysis*

48. Figure 7 shows the time series for 2 year, 3 and 5 year rolling betas. It can be seen that these have been on a rising trend since Henry completed his study (signified by the black dotted vertical line in the below figures).

**Figure 7: Weighted portfolio rolling weekly recursive re-levered equity beta**



*Bloomberg data, CEG analysis*

## 7 Structural Change

49. Given the evidence described in previous chapters indicates a rise in re-levered equity, tests are carried out to determine if the rise can be reliably determined to be a systematic change in beta itself rather than due to randomness in the data.
50. The Quandt-Andrews test<sup>15</sup> is applied to test for the existence of a structural break in asset beta estimates. This is the standard approach to structural break estimation in the modern statistics literature. In doing so we have used the statistical package `strucchange`<sup>16</sup> in R. The test asks whether the asset beta before a hypothetical breakpoint is significantly different compared to the asset beta after the breakpoint. The test compares all possible breakpoints and this facet of the test is incorporated into the significance testing.<sup>17</sup> The null hypothesis is that there is no structural break and that asset betas in each period are the same. If the null hypothesis is rejected, the test finds there exists a breakpoint where the asset beta estimated before the breakpoint is significantly different from the asset beta estimated after the breakpoint. In order to apply the Quandt-Andrews test, the estimation equation is transformed so that the asset beta enters directly into the estimating equation through its function with equity beta.<sup>18</sup>
51. Table 18 shows the result of the Quandt-Andrews test for Henry's Portfolio 6<sup>19</sup> (noting that portfolio 6 is the only portfolio for which all of the constituents have data to October 2016). The Quandt-Andrews test rejects the null hypothesis for both equal weighted and value weighted portfolios - with p-values below 3%. Also both results show that the date with the highest probability of structural change is on 7<sup>th</sup>, August 2009, which lies during the GFC. This is illustrated in Figure 8 and Figure 9

<sup>15</sup> See Hansen, Bruce E. "The New Econometrics of Structural Change: Dating Breaks in U.S. Labor Productivity", *Journal of Economic Perspectives*, Vol 15, No 4 Fall 2001, pg. 117-128 for a description of the Quandt-Andrews test.

<sup>16</sup> Achim Zeileis, Friedrich Leisch, Kurt Hornik and Christian Kleiber (2002). `strucchange`: An R Package for Testing for Structural Change in Linear Regression Models. *Journal of Statistical Software*, 7(2), 1-38. URL <http://www.jstatsoft.org/v07/i02/>

<sup>17</sup> That is, the fact that all possible break points are examined would, using the older Chow test, materially increase the probability of finding a 'significant' structural break simply due to the number of breakpoints tested. In fact, the Chow test was only statistically valid if applied to a single breakpoint that was theoretically identified by the user without prior inspection of the data. The Quandt-Andrews test accounts for this by testing all possible break points but simultaneously also 'raising the bar', relative to the Chow test, for a finding of statistical significance.

<sup>18</sup> See Greene William H., "Econometric Analysis" 7<sup>th</sup> edition, Pearson, 2012 for details on variable transformation or Appendix C for a numeric illustration.

<sup>19</sup> Quandt-Andrews test is also applied to other portfolios, shown in Appendix D. In all scenarios where the portfolio is extended to October 2016, the test determines significance for two breakpoints, one during the GFC and another between 2013 and 2014.

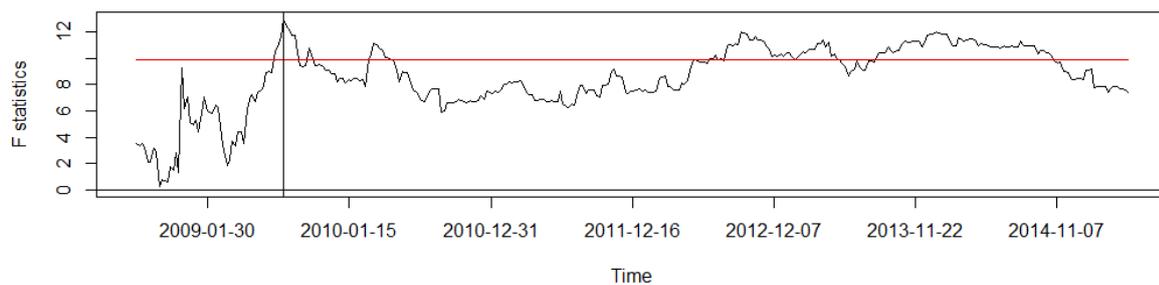
which displays the F statistics across time. The highest F statistics occurs on in August 2009 shown by the black vertical line.

**Table 18: Result of Quandt-Andrews test on the whole sample (portfolio 6)**

	Equal weighted portfolio	Value weighted portfolio
P-value	0.02727	0.0027
Date of Maximum Fstatistic	07/08/2009	07/08/2009
Estimated Asset Beta for Whole Sample	0.18	0.17
Estimated Asset Beta prior to breakpoint	0.14	0.12
Estimated Asset Beta after breakpoint	0.23	0.24

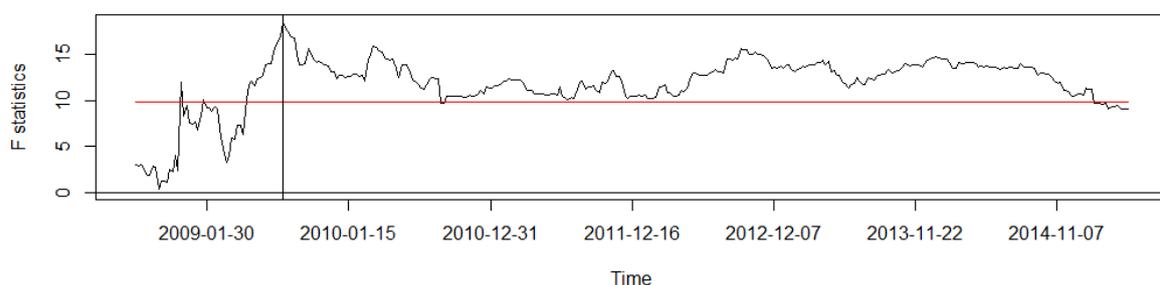
*Bloomberg Data, CEG Analysis*

**Figure 8: F-statistics for equal weighted portfolio**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 9: F-statistics for value weighted portfolio**



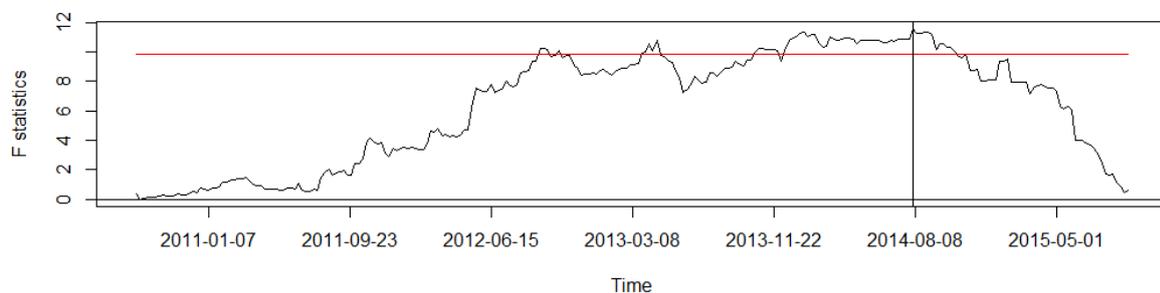
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

52. The Quandt-Andrews test only identifies a single breakpoint, it does not test the number of breakpoints. Figure 8 and Figure 9 shows that the period during the GFC has the highest probability of a breakpoint, however it does not preclude additional breakpoints. In fact the F statistics between beginning of 2012 and end of 2014 also lies above the 10% p-value cut-off. This indicates that there may be a second

breakpoint during that period. Therefore a sub-sample is taken for the period after the 7/08/2009 break-point to examine if there exist a second breakpoint.

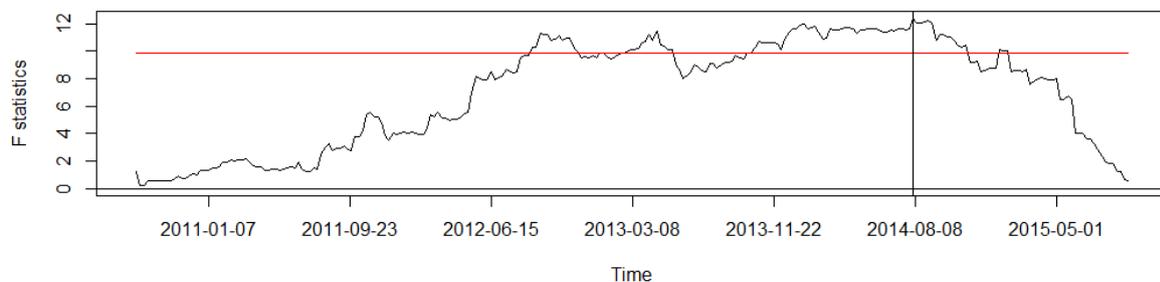
53. The result of the Quandt-Andrews test on the sub-sample is illustrated in Figure 10 and Figure 11. The Quandt-Andrews test using both value weighted and equal weighted portfolios identify a second break point for the sample after the GFC. The F-statistics peaks on 8<sup>th</sup> August 2014, indicating that is the most likely date of the break.

**Figure 10: F-statistics for equal weighted portfolio (after GFC)**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 11: F-statistics for value weighted portfolio (after GFC)**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

54. Details of the test are shown in Table 19. Stability for the period after the GFC is rejected with a p-value less than 5%. When the re-levered equity beta is calculated assuming the beta is constant, the estimate is 0.58-0.6. However when the breakpoint is taken into account, the estimation shows that there is a large difference in the re-levered equity beta before and after August 2014. The re-levered equity beta prior to August 2014 is only 0.5-0.53, however it increases to 0.88 to 0.9 after the August 2014.
55. The re-levered equity beta of 0.88 to 0.9 after August 2014 is based on a little over 2 years of data. However, Figure 10 and Figure 11 illustrate that there are high F-

statistics from late 2012 to late 2014 suggesting that discernible differences in asset beta began presenting in the data up-to two years prior to the maximum F-statistic observed for August 2014. This suggests that, when attempting to arrive at a post-break asset beta estimate it is reasonable to also have regard to 3 and 4 year beta estimates. As per Table 16 and Table 17 these range from 0.79 to 0.85. This suggests a post-structural break estimate for the re-levered equity beta of 0.8 (based on 3-4 year betas) to 0.9 (based on the identified date of the highest F-statistic).

**Table 19: Quandt-Andrews test on the sample after GFC (portfolio 6)**

	<b>Equal Weighted Portfolio</b>	<b>Value Weighted Portfolio</b>
P-value	0.04996	0.03535
Date of maximum F-statistic	08/08/2014	08/08/2014
Estimated asset beta for sample after GFC	0.23	0.24
Estimated asset beta prior to breakpoint	0.20	0.21
Estimated asset beta after breakpoint	0.35	0.36
Estimated re-levered equity beta for sample after GFC	0.58	0.60
Estimated re-levered equity beta prior to breakpoint	0.50	0.53
Estimated re-levered equity beta after breakpoint	0.88	0.90

## 8 Summary of replication and extension results

56. We have also replicated and extended Henry's table 3, 15, 17, A2, A5 and A7 associated the sampling period excluding the technology boom (prior to 2002) and the GFC period (29/08/2008 to 06/11/2009). The detailed results are can be found in Appendix B.
57. Table 20 below summarises the result from our extension to Henry's individual stock beta analysis. This table is directly compared with Table 3-35 from the United Energy distribution determination final decision. Evidence suggests that, ignoring evidence on structural breaks and continuing to use the long tome periods (i.e., more than 5 years) beta has increased around 0.08 to 0. since the end of Henry's sampling period (0.23 if only the last 5 years are used).

**Table 20: Summary of extension results for re-levered OLS weekly individual beta estimates**

	Longest available period	Longest available period (excl. tech boom and GFC)	Last five years
Henry original results	0.52	0.56	0.46
CEG extension results	0.60	0.66	0.69
<b>Change</b>	<b>0.08</b>	<b>0.10</b>	<b>0.23</b>

*Bloomberg data, CEG analysis*

58. It should be noted that Henry's average "last five years" beta estimates includes six firms (APA, DUE, DNV, HDF, SKI and AST), among which ENV and HDF were delisted in 2013 and 2014, respectively. Including these two stocks at the time of our estimates (October 2016) would result in a considerably less number of observations than other stocks (153 for ENV and 59 for HDF as compared with 261 for others). Therefore, our "last five years" beta estimates is only averaged across the four currently listed firms as in Table 13.
59. Table 21 below shows the measured betas for the six portfolios as outlined in section 4.1 for the two sampling periods. Portfolio 5 is the only portfolio comprised of firms with additional data (portfolio 6 is added by CEG and is the same as Portfolio 5 but excludes Envestra). Compared with Table 3-36 from the United Energy distribution determination final decision, and focusing on portfolio 5, Table 21 suggests that average portfolio betas has since then increased by around 0.15 or more.



**Table 21: Summary of extension results for re-levered OLS weekly portfolio beta estimates**

	<b>P1</b>	<b>P2</b>	<b>P3</b>	<b>P4</b>	<b>P5</b>	<b>P6</b>
<b>Equal weighted</b>						
Longest available period	0.55	0.52	0.52	0.53	0.54	0.55
Increase vs Henry	0.09	0.00	0.01	0.05	0.15	N/A
Longest available period (excl. tech boom and GFC)	0.61	0.52	0.58	0.60	0.63	0.65
Increase vs Henry	0.11	0.00	0.03	0.07	0.17	N/A
<b>Value weighted</b>						
Longest available period	0.63	0.70	0.45	0.47	0.56	0.57
Increase vs Henry	0.13	0.00	0.01	0.05	0.17	N/A
Longest available period (excl. tech boom and GFC)	0.69	0.70	0.54	0.57	0.66	0.68
Increase vs Henry	0.16	0.00	0.02	0.06	0.19	N/A

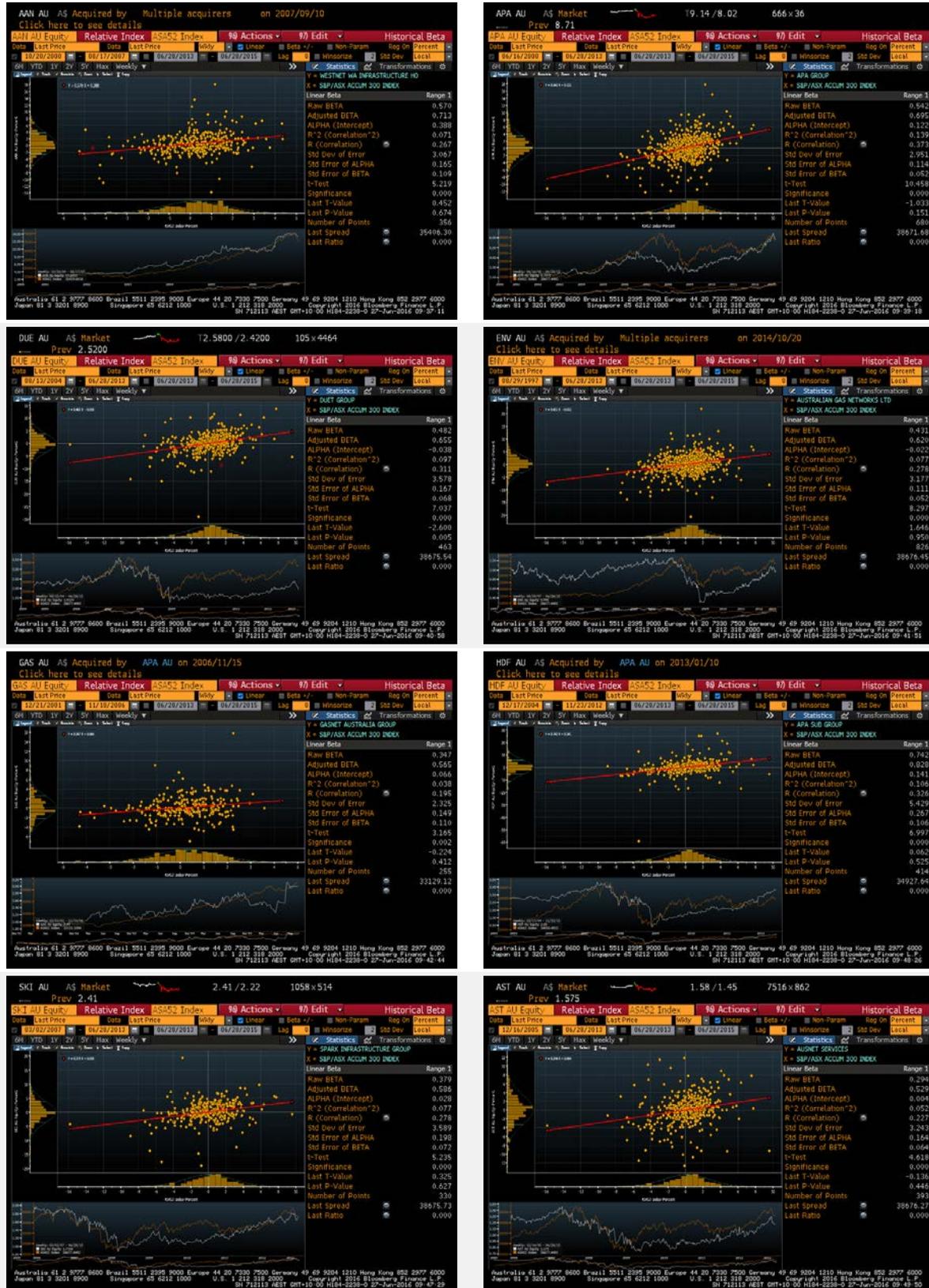
*Bloomberg data, CEG analysis*



## Appendix A Bloomberg historical beta screenshots

60. Figure 12 shows a number of screenshots from the Bloomberg “Historical beta” field for AAN, APA, DUE, ENU, GAS, HDF, SKI and AST. The “Raw Beta” in the right sidebar column can be compared directly with “equity beta” column in Table 6 of this report. This demonstrates that our estimates of the equity beta is consistent with Bloomberg’s measure while being slightly different to the figures in Henry (2014).

Figure 12: Bloomberg historical beta screenshots



## Appendix B CEG replication and extension of Henry's beta analysis (post tech boom and excluding the GFC)

### B.1 Individual stocks beta

#### B.1.1 CEG replication of Henry's Table 3 and A2

Stock	Equity beta	Asset beta	W	Gearing	Re-levered equity beta_ceg (replication)	Re-levered equity beta_henry (actual)
AAN	0.64	0.40	1.55	0.38	1.00	1.00
AGL	0.43	0.30	1.77	0.29	0.76	0.75
APA	0.57	0.27	1.16	0.54	0.66	0.64
DUE	0.50	0.13	0.64	0.75	0.32	0.30
ENV	0.48	0.14	0.76	0.70	0.36	0.37
GAS	0.35	0.13	0.90	0.64	0.32	0.32
HDF	0.68	0.41	1.49	0.40	1.02	0.91
SKI	0.38	0.22	1.42	0.43	0.54	0.34
AST	0.46	0.19	1.02	0.59	0.48	0.47
<b>Average</b>	<b>0.50</b>	<b>0.24</b>	<b>1.19</b>	<b>0.52</b>	<b>0.61</b>	<b>0.56</b>

*Bloomberg data, CEG analysis*

#### B.1.2 CEG extension of Henry's Table 3 and A2

Stock	Equity beta	Asset beta	W	Gearing	Re-levered equity beta_ceg (replication)	Re-levered equity beta_ceg (extension)	Change
AAN	0.64	0.40	1.55	0.38	1.00	NA	NA
AGL	0.43	0.30	1.77	0.29	0.76	NA	NA
APA	0.61	0.31	1.27	0.49	0.66	0.78	0.12
DUE	0.46	0.15	0.78	0.69	0.32	0.36	0.04
ENV	0.48	0.16	0.82	0.67	0.36	0.39	0.03
GAS	0.35	0.13	0.90	0.64	0.32	NA	NA
HDF	0.68	0.41	1.49	0.40	1.02	NA	NA
SKI	0.45	0.29	1.62	0.35	0.54	0.73	0.19
AST	0.54	0.23	1.06	0.58	0.48	0.57	0.10
							<b>0.04-0.19</b>

*Bloomberg data, CEG analysis*

## B.2 Portfolio beta

### B.2.1 CEG replication of Henry's Table 15 and A5

Portfolio	Equity beta	Asset beta	W	Gearing	Re-levered equity beta_ceg (replication)	Re-levered equity beta_henry (actual)
p1	0.52	0.20	0.96	0.62	0.50	0.49
p2	0.42	0.21	1.25	0.50	0.52	0.52
p3	0.58	0.23	1.01	0.60	0.58	0.55
p4	0.57	0.24	1.06	0.57	0.60	0.53
p5	0.52	0.21	1.01	0.59	0.53	0.45
p6	0.52	0.22	1.06	0.57	0.55	-
<b>Average</b>	<b>0.52</b>	<b>0.22</b>	<b>1.06</b>	<b>0.58</b>	<b>0.55</b>	<b>0.51</b>

*Bloomberg data, CEG analysis*

### B.2.2 CEG extension of Henry's Table 15 and A5

Portfolio	equity beta	asset beta	w	gearing	re-levered equity beta_CEG (replication)	re-levered equity beta_CEG (extension)	change
p1	0.58	0.24	1.05	0.58	0.50	0.61	0.10
p2	0.42	0.21	1.25	0.50	0.52	NA	NA
p3	0.58	0.23	1.01	0.60	0.58	NA	NA
p4	0.57	0.24	1.06	0.57	0.60	NA	NA
p5	0.55	0.25	1.14	0.54	0.53	0.63	0.10
p6	0.55	0.26	1.20	0.52	0.55	0.65	0.10
							<b>0.10</b>

*Bloomberg data, CEG analysis*

### B.2.3 CEG replication of Henry's Table 17 and A7

Portfolio	Equity beta	Asset beta	W	Gearing	Re-levered equity beta_ceg (replication)	Re-levered equity beta_henry (actual)
p1	0.54	0.22	1.02	0.59	0.55	0.54
p2	0.44	0.28	1.58	0.37	0.70	0.70
p3	0.55	0.22	0.97	0.61	0.54	0.52
p4	0.54	0.23	1.04	0.58	0.57	0.50
p5	0.53	0.22	1.04	0.59	0.55	0.48
p6	0.53	0.22	1.06	0.58	0.56	-
<b>Average</b>	<b>0.52</b>	<b>0.23</b>	<b>1.13</b>	<b>0.55</b>	<b>0.58</b>	<b>0.55</b>

*Bloomberg data, CEG analysis*



### B.2.4 CEG extension of Henry's Table 17 and A7

Portfolio	Equity beta	Asset beta	W	Gearing	Re-levered equity beta_ceg (replication)	Re-levered equity beta_ceg (extension)	Change
p1	0.59	0.28	1.16	0.53	0.55	0.69	0.14
p2	0.44	0.28	1.58	0.37	0.70	NA	NA
p3	0.55	0.22	0.97	0.61	0.54	NA	NA
p4	0.54	0.23	1.04	0.58	0.57	NA	NA
p5	0.57	0.27	1.16	0.53	0.55	0.66	0.12
p6	0.57	0.27	1.19	0.53	0.56	0.68	0.12
							<b>0.12-0.14</b>

Bloomberg data, CEG analysis

### B.2.5 CEG extension of weekly portfolio (equal weighted, ignoring tech boom and GFC) beta estimates for the most recent 5 years

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (Henry end date replicated)	Re-levered equity beta (CEG extension)	Change
P1	0.61	0.30	1.22	0.51	0.54	0.75	0.20
P5	0.53	0.27	1.26	0.50	0.46	0.67	0.20
P6	0.53	0.27	1.30	0.48	0.47	0.69	0.22
<b>Average</b>	<b>0.56</b>	<b>0.28</b>	<b>1.26</b>	<b>0.50</b>	<b>0.49</b>	<b>0.70</b>	<b>0.21</b>

Bloomberg data, CEG analysis

### B.2.6 CEG extension of weekly portfolio (value weighted, ignoring tech boom and GFC) beta estimates for the most recent 5 years

Bloomberg ticker	Equity beta	Asset beta	W	Gearing	Re-levered equity beta (Henry end date replicated)	Re-levered equity beta (CEG extension)	Change
P1	0.60	0.31	1.30	0.48	0.59	0.78	0.19
P5	0.56	0.28	1.26	0.50	0.49	0.70	0.22
P6	0.56	0.29	1.28	0.49	0.49	0.71	0.22
<b>Average</b>	<b>0.57</b>	<b>0.29</b>	<b>1.28</b>	<b>0.49</b>	<b>0.53</b>	<b>0.73</b>	<b>0.21</b>

Bloomberg data, CEG analysis

## Appendix C Variable transformation

61. In order to determine the asset beta it is common for a two-step process to be used which, first estimates the equity beta by regressing stock returns and market returns:

$$R_{et} = c + \beta_e R_{mt} + \varepsilon_t.$$

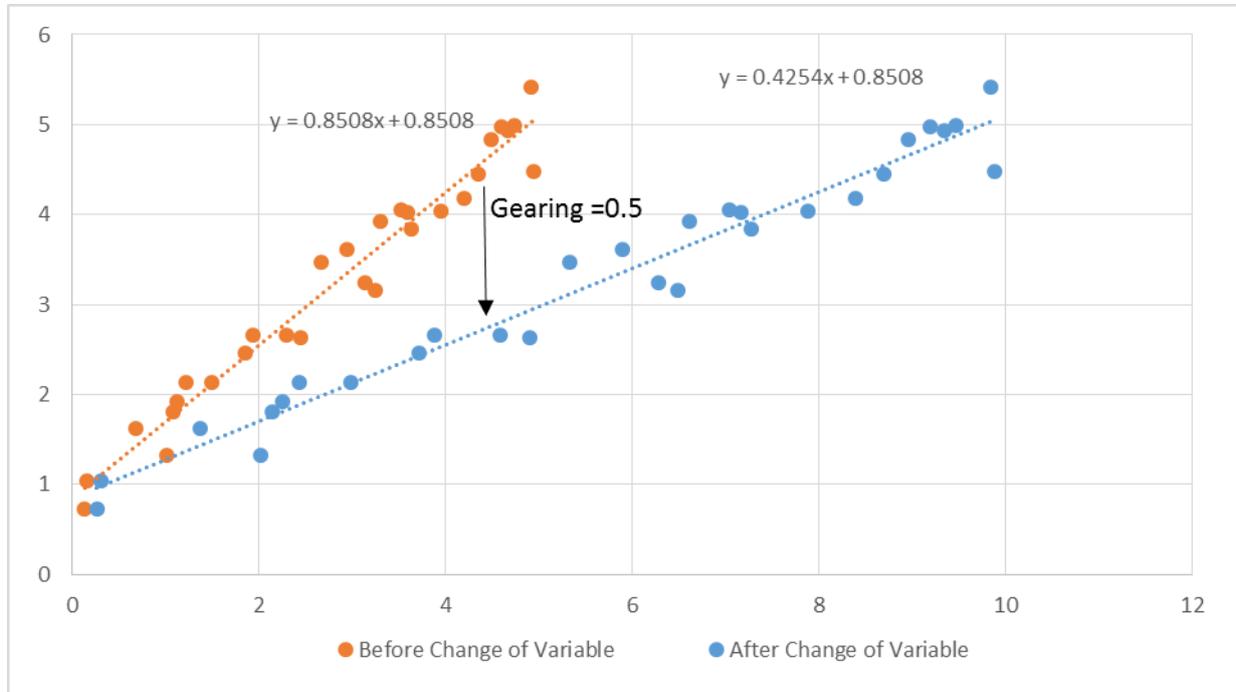
62.  $R_{et}$  is the return of the equity at time  $t$  and  $R_{mt}$  is the market return at time  $t$ .  $\beta_e$  is the estimated equity beta over the sample period. With the equity beta so estimated it is necessary to then determine the asset beta which is calculated through the equation

$$\beta_a = \beta_e(1 - \bar{G}).$$

$\beta_a$  is the asset beta and  $\bar{G}$  is the average gearing over the sample period.

63. In order to test for a structural change in asset beta it is necessary to combine these two steps into a single process such that the impact of both steps be simultaneously tested for pre and post a given date (i.e., pre and post a possible date for structural change).
64. In order to do this it is necessary to estimate the asset beta directly by transforming the independent variable in the regression equation. The relationship between the asset beta and the equity beta can be rewritten in the form  $\frac{\beta_a}{(1-\bar{G})} = \beta_e$  and merged into the estimating equation to become  $R_{et} = c + \frac{\beta_a}{(1-\bar{G})} R_{mt} + \varepsilon_t$ . Thus the asset beta can be estimated directly using the equation  $R_{et} = c + \beta_a \frac{R_{mt}}{(1-\bar{G})} + \varepsilon_t$ .
65. The asset beta estimated based on the two approaches are equivalent. This is illustrated in Figure 13, which demonstrates the change of variable on simulated numbers. The orange dots shows the original data points and the estimated equation  $y = 0.8508x + 0.8508$ . The slope, 0.8508, can be viewed as the equity beta and asset beta becomes 0.4254 if the gearing is assumed to be 0.5. Alternatively, if the x variable is adjusted to the form,  $\frac{x}{(1-0.5)}$ , which stretches out the data points along the x axis as shown in the blue dots, the estimated coefficient is exactly 0.4254. The constant is also the same as the original estimating equation.

**Figure 13: Example of variable transformation**



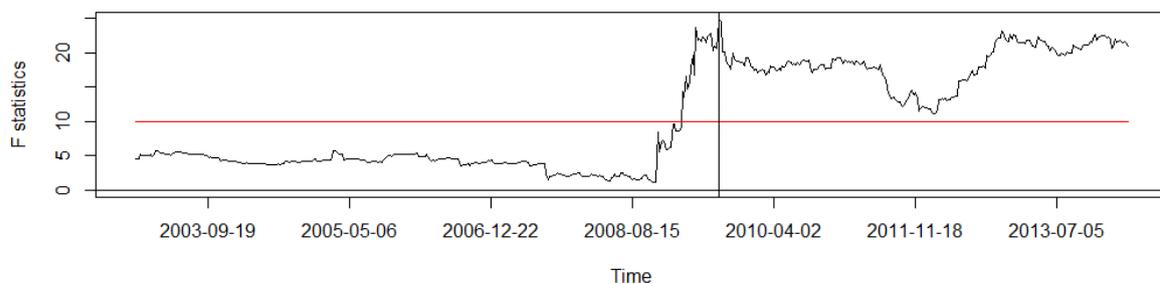
66. Estimating the asset beta directly allows us to account for the variability in the gearing ratio through time. Given that gearing varies through time and that this influences the measured asset beta (for any given equity beta) it is necessary to account for that variation in gearing when testing for a change in the measured asset beta. This is achieved by estimating asset beta directly in the regression.

$$R_{et} = c + \beta_a \frac{R_{mt}}{(1-G_t)} + \varepsilon_t.$$

## Appendix D Additional results on structural break

67. This section uses the Quandt-Andrews test to test for structural breaks in portfolios 1 to 5<sup>20</sup>. The test is applied to estimated asset beta directly using the variable transformation methodology described in Appendix C.
68. For the only two portfolios, portfolio 1 and portfolio 5, which have observations for most current period, both share similar results compared to portfolio 6. The result shows two breakpoints in portfolio 1 and portfolio 5. The first breakpoint occurs during the GFC. Using only data post this breakpoint a second breakpoint occurs in August of 2014.
69. The Quandt-Andrews test also rejected for stability for portfolio 2 which ended in 2006. It found a single breakpoint in 2003. Stability is not rejected for portfolio 3 and 4 with p-value between 0.2 and 0.1. However the p value is very close to the 0.1 cutoff and the test did not reject the opposite null hypothesis (i.e., that a structural break exists). The test also finds that the break to most likely to have occurred during the GFC.

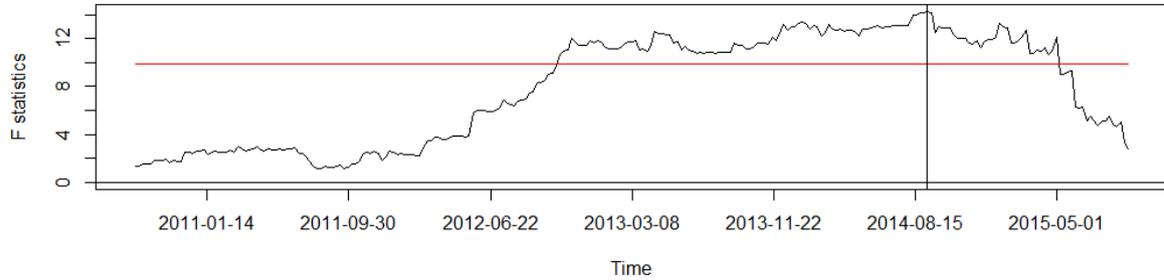
**Figure 14: Portfolio 1, equal weighted, breakpoint 1**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

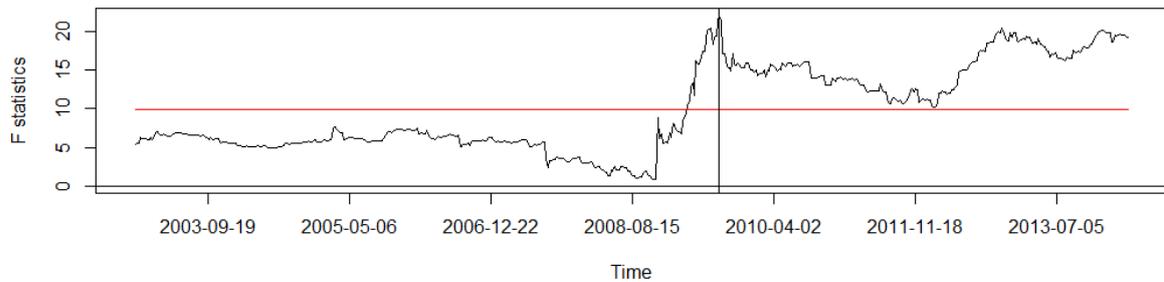
<sup>20</sup> Description of the portfolios is in Table 7.

**Figure 15: Portfolio 1, equal weighted, breakpoint 2**



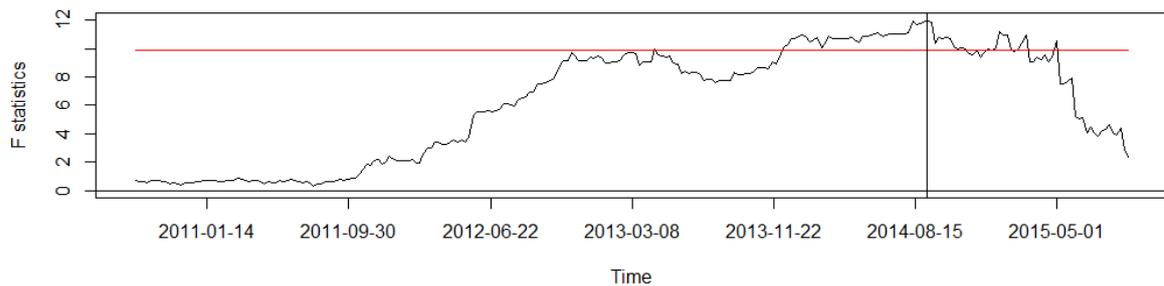
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 16: Portfolio 1, value weighted, breakpoint 1**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 17: Portfolio 1, value weighted, breakpoint 2**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

### D.1.1 Statistics for breakpoint 1 (portfolio 1)

	Equal Weighted Portfolio	Value Weighted Portfolio
P-value	0.0001	0.0004
Date of Maximum Fstatistic	14/08/2009	14/08/2009
Estimated Asset Beta for Whole Sample	0.17	0.18
Estimated Asset Beta prior to breakpoint	0.13	0.15
Estimated Asset Beta after breakpoint	0.25	0.27

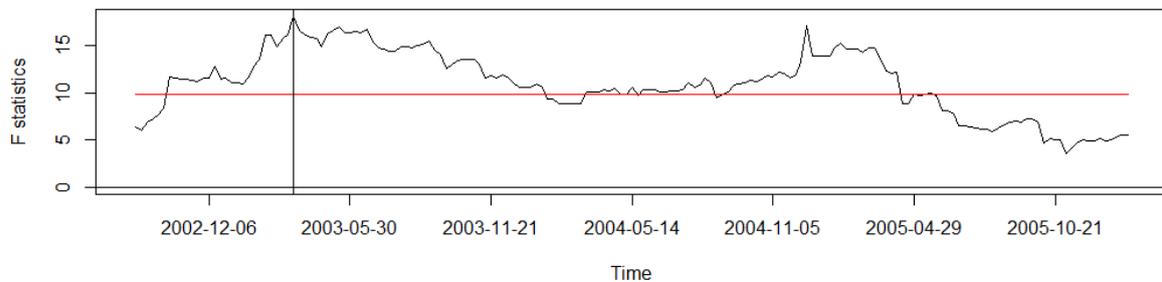
*Bloomberg Data, CEG Analysis*

### D.1.2 Statistics for breakpoint 2 (portfolio 1)

	Equal Weighted Portfolio	Value Weighted Portfolio
P-value	0.0158	0.0416
Date of Maximum Fstatistic	05/09/2014	05/09/2014
Estimated Asset Beta for Whole Sample	0.25	0.27
Estimated Asset Beta prior to breakpoint	0.22	0.23
Estimated Asset Beta after breakpoint	0.42	0.42

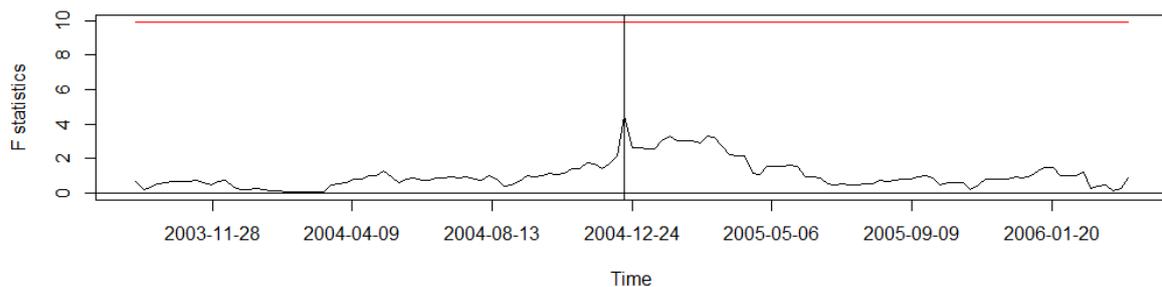
*Bloomberg Data, CEG Analysis*

**Figure 18: Portfolio 2, equal weighted, breakpoint 1**



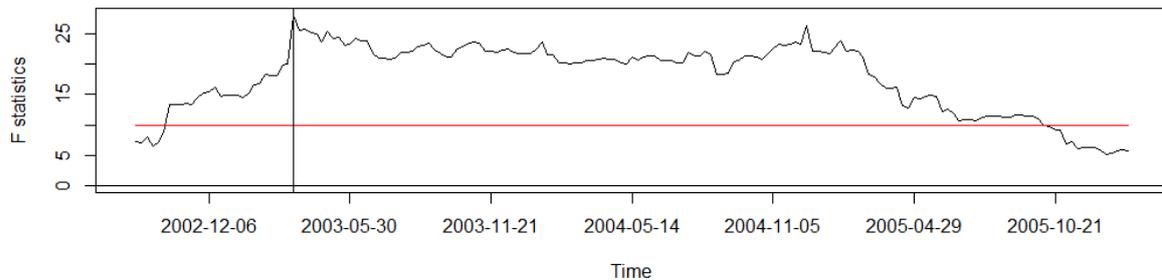
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 19: Portfolio 2, equal weighted, breakpoint 2**



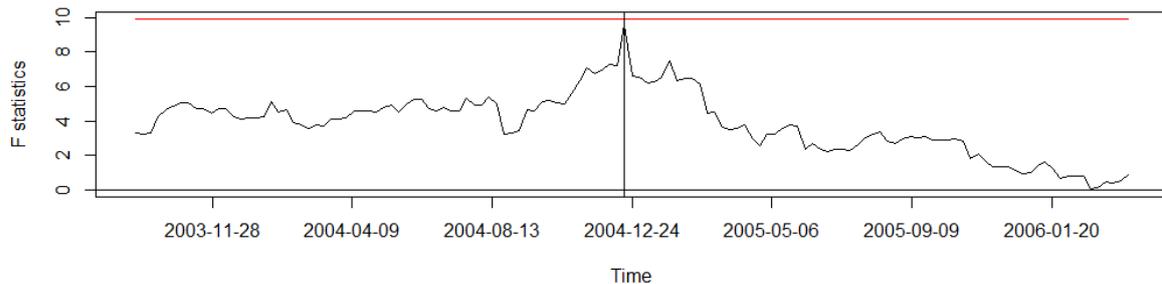
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 20: Portfolio 2, value weighted, breakpoint 1**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 21: Portfolio 2, value weighted, breakpoint 2**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

### **D.1.3 Statistics for breakpoint 1 (portfolio 2)**

	<b>Equal Weighted Portfolio</b>	<b>Value Weighted Portfolio</b>
P-value	0.0028	0.0000
Date of Maximum Fstatistic	21/03/2003	21/03/2003
Estimated Asset Beta for Whole Sample	0.20	0.25
Estimated Asset Beta prior to breakpoint	0.05	0.00
Estimated Asset Beta after breakpoint	0.29	0.42

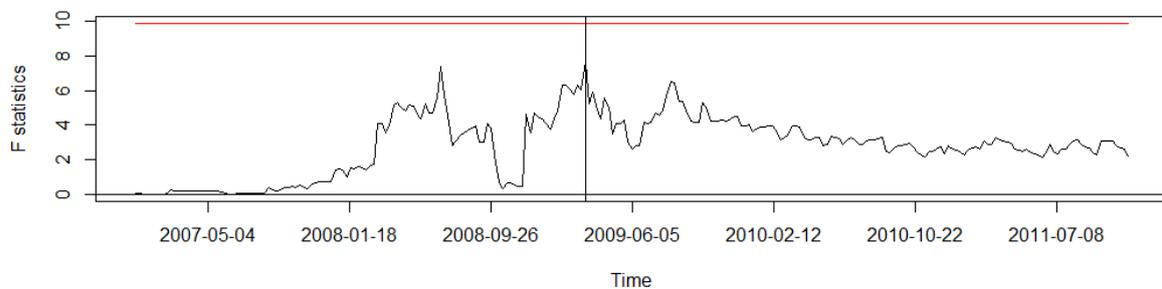
*Bloomberg Data, CEG Analysis*

### D.1.4 Statistics for breakpoint 2 (portfolio 2)

	Equal Weighted Portfolio	Value Weighted Portfolio
P-value	0.6623	0.1146
Date of Maximum Fstatistic	17/12/2004	17/12/2004
Estimated Asset Beta for Whole Sample	0.29	0.42
Estimated Asset Beta prior to breakpoint	0.19	0.24
Estimated Asset Beta after breakpoint	0.33	0.53

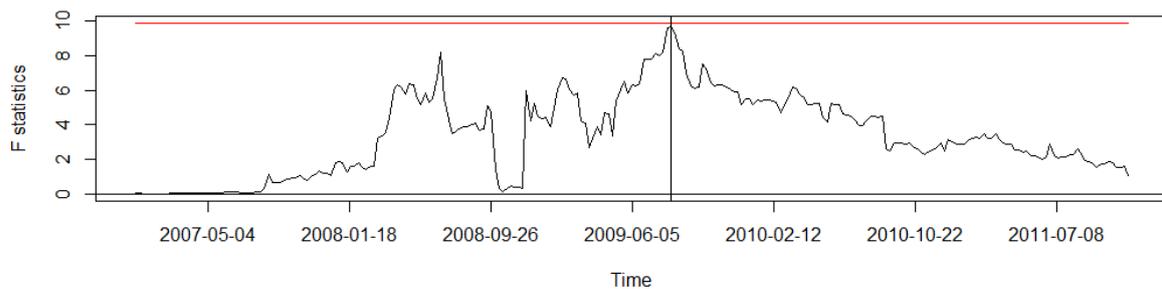
*Bloomberg Data, CEG Analysis*

**Figure 22: Portfolio 3, equal weighted, breakpoint 1**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 23: Portfolio 3, value weighted, breakpoint 1**



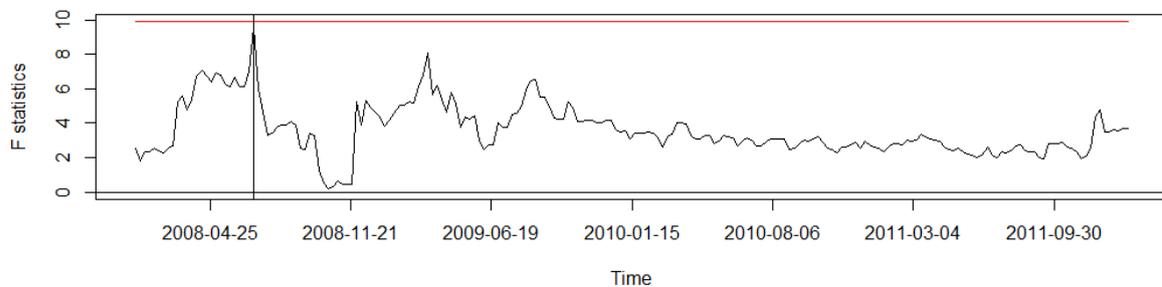
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

### D.1.5 Statistics for breakpoint 1 (portfolio 3)

	Equal Weighted Portfolio	Value Weighted Portfolio
P-value	0.2346	0.1087
Date of Maximum Fstatistic	13/03/2009	14/08/2009
Estimated Asset Beta for Whole Sample	0.20	0.16
Estimated Asset Beta prior to breakpoint	0.17	0.13
Estimated Asset Beta after breakpoint	0.19	0.21

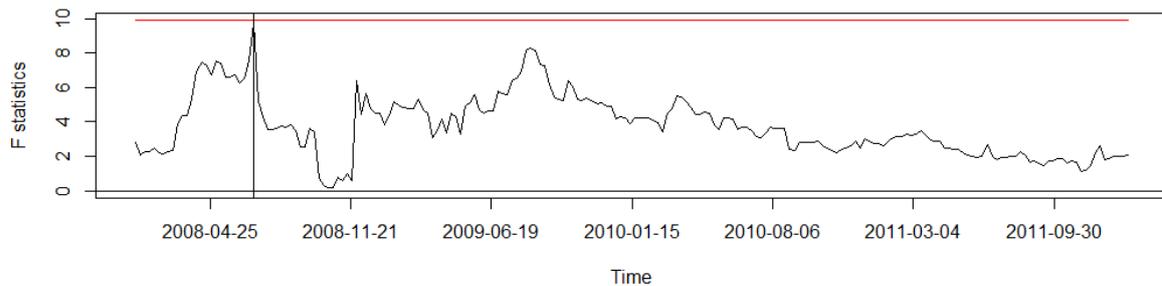
*Bloomberg Data, CEG Analysis*

**Figure 24: Portfolio 4, equal weighted, breakpoint 1**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 25: Portfolio 4, value weighted breakpoint 1**



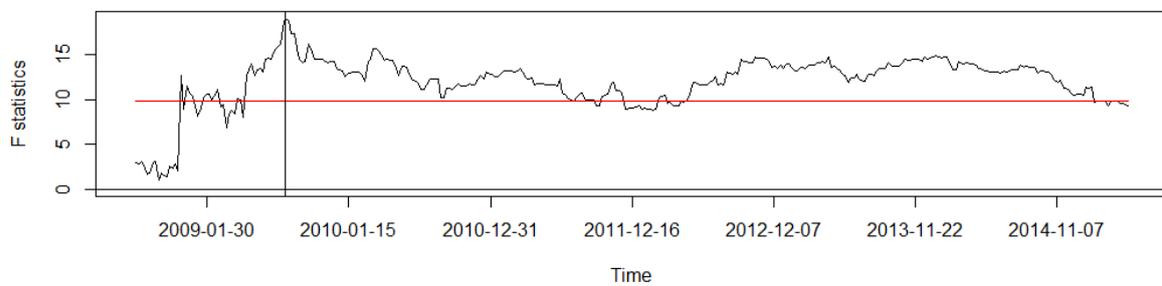
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

### D.1.6 Statistics for breakpoint 1 (portfolio 4)

	Equal Weighted Portfolio	Value Weighted Portfolio
P-value	0.1152	0.1052
Date of Maximum Fstatistic	27/06/2008	27/06/2008
Estimated Asset Beta for Whole Sample	0.19	0.17
Estimated Asset Beta prior to breakpoint	0.31	0.30
Estimated Asset Beta after breakpoint	0.18	0.15

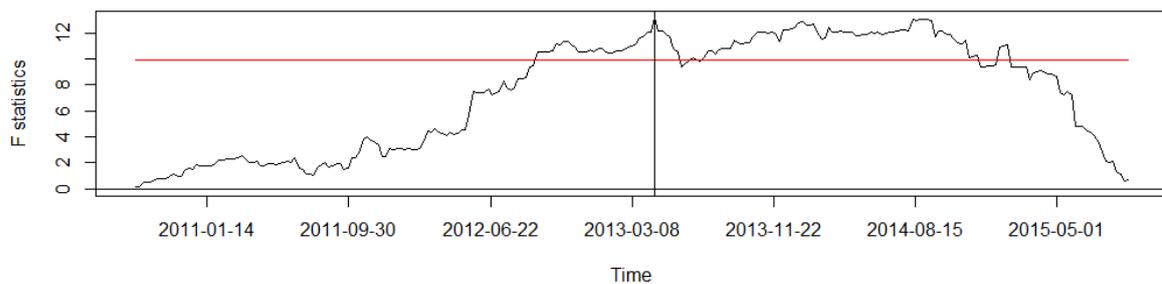
*Bloomberg Data, CEG Analysis*

**Figure 26: Portfolio 5, equal weighted, breakpoint 1**



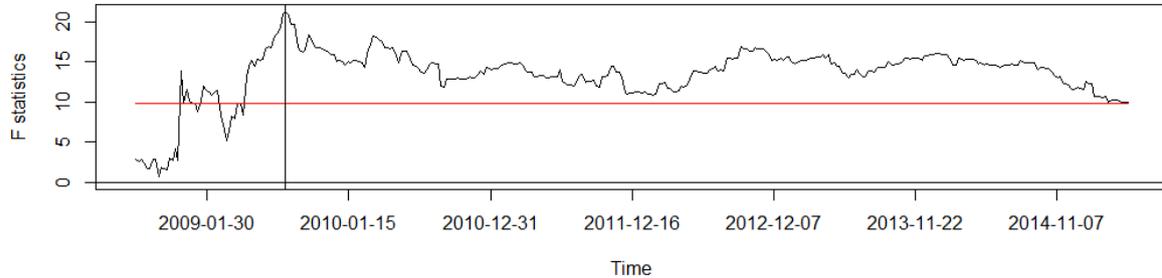
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 27: Portfolio 5, equal weighted, breakpoint 2**



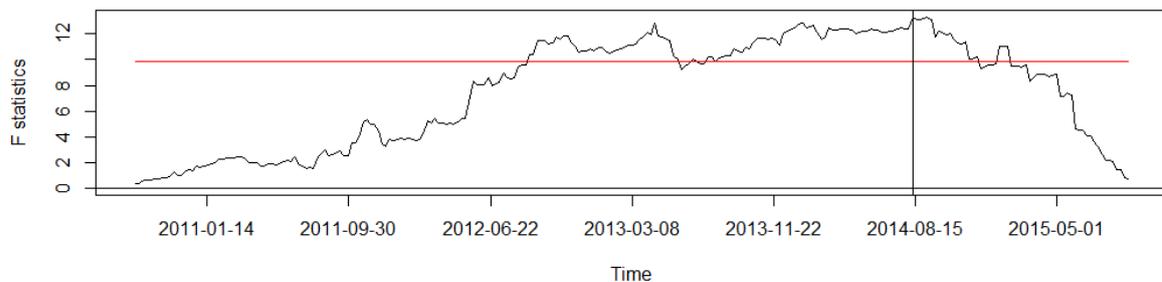
*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 28: Portfolio 5, value weighted, breakpoint 1**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

**Figure 29: Portfolio 5, value weighted, breakpoint 2**



*Bloomberg Data, CEG Analysis, the red line indicates 10% p-value for the supF test*

### D.1.7 Statistics for breakpoint 1 (portfolio 5)

	Equal Weighted Portfolio	Value Weighted Portfolio
P-value	0.0018	0.0007
Date of Maximum Fstatistic	14/08/2009	14/08/2009
Estimated Asset Beta for Whole Sample	0.17	0.17
Estimated Asset Beta prior to breakpoint	0.13	0.12
Estimated Asset Beta after breakpoint	0.23	0.24

*Bloomberg Data, CEG Analysis*



### **D.1.8 Statistics for breakpoint 2 (portfolio 5)**

	<b>Equal Weighted Portfolio</b>	<b>Value Weighted Portfolio</b>
P-value	0.0259	0.0239
Date of Maximum Fstatistic	19/04/2013	08/08/2014
Estimated Asset Beta for Whole Sample	0.23	0.24
Estimated Asset Beta prior to breakpoint	0.19	0.21
Estimated Asset Beta after breakpoint	0.32	0.36

*Bloomberg Data, CEG Analysis*