

Matlab Code

```
1 %% Important notes:
2 % To run this script you need the dataset "Spot+DecFutures.xlsx".
3 % The code must be run sectionwise, as structured here.
4 % Some of the subsections must be runned separately, such as plots and
5 % figures.
6 % If you have any issues with running the script, please contact
7 % sander.lie@student.bi.no
8
9 %% Part 1 – Preliminary analysis:
10 % Risk Premium statistics
11 clear;
12 clc;
13
14 % Import data and create variables:
15 data = readtable('Spot+DecFutures.xlsx');
16 data=data(~any(ismissing(data.Spot),2),:);
17 data(584:585,:) = [];
18 data = table2timetable(data);
19 data.RP19 = data.Fut19 - data.Spot;
20 data.RP18 = data.Fut18 - data.Spot;
21 data.RP17 = data.Fut17 - data.Spot;
22 data.RP16 = data.Fut16 - data.Spot;
23 data.RP15 = data.Fut15 - data.Spot;
24 data.RP14 = data.Fut14 - data.Spot;
25 data(1700:end,:) = [];
26
27 % Statistics:
28 Results = table();
29 Results.Observations(1) = 1699;
30 Results.Observations(2) = 1454;
31 Results.Observations(3) = 1207;
32 Results.Observations(4) = 983;
33 Results.Observations(5) = 729;
34 Results.Observations(6) = 485;
35
36 Results.Mean(1) = mean(data.RP19(1:1699));
37 Results.Mean(2) = mean(data.RP18(1:1454));
38 Results.Mean(3) = mean(data.RP17(1:1207));
39 Results.Mean(4) = mean(data.RP16(1:983));
40 Results.Mean(5) = mean(data.RP15(1:729));
41 Results.Mean(6) = mean(data.RP14(1:485));
42
43 Results.Std(1) = std(data.RP19(1:1699));
44 Results.Std(2) = std(data.RP18(1:1454));
45 Results.Std(3) = std(data.RP17(1:1207));
46 Results.Std(4) = std(data.RP16(1:983));
47 Results.Std(5) = std(data.RP15(1:729));
48 Results.Std(6) = std(data.RP14(1:485));
49
50 Results.Skew(1) = skewness(data.RP19(1:1699));
51 Results.Skew(2) = skewness(data.RP18(1:1454));
52 Results.Skew(3) = skewness(data.RP17(1:1207));
53 Results.Skew(4) = skewness(data.RP16(1:983));
54 Results.Skew(5) = skewness(data.RP15(1:729));
55 Results.Skew(6) = skewness(data.RP14(1:485));
56
57 Results.ExKurt(1) = kurtosis(data.RP19(1:1699))-3;
58 Results.ExKurt(2) = kurtosis(data.RP18(1:1454))-3;
59 Results.ExKurt(3) = kurtosis(data.RP17(1:1207))-3;
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60 Results.ExKurt(4) = kurtosis(data.RP16(1:983))-3;
61 Results.ExKurt(5) = kurtosis(data.RP15(1:729))-3;
62 Results.ExKurt(6) = kurtosis(data.RP14(1:485))-3;
63
64 figure;
65 plot(data.Date, data.RP19)
66 hold on
67 plot(data.Date, data.RP18)
68 plot(data.Date, data.RP17)
69 plot(data.Date, data.RP16)
70 plot(data.Date, data.RP15)
71 plot(data.Date, data.RP14)
72 hold off
73 legend('RP 19', 'RP 18', 'RP 17', 'RP 16', 'RP 15', 'RP 14')
74 box('off')
75 xlabel('Year');
76 ylabel('Risk Premium in EUR')
77
78 % Historical prices of emission allowances
79 figure;
80 plot(data.Date, data.Spot)
81 hold on
82 plot(data.Date, data.Fut19);
83 plot(data.Date, data.Fut18);
84 plot(data.Date, data.Fut17);
85 plot(data.Date, data.Fut16);
86 plot(data.Date, data.Fut15);
87 plot(data.Date, data.Fut14);
88 legend('Spot', 'Fut19', 'Fut18', 'Fut17', 'Fut16', 'Fut15', 'Fut14', '
      Location', 'SouthEast')
89 xlabel('Year');
90 ylabel('Price (in EUR)');
91 hold off
92
93 %% Part 2 – ADF tests
94 clear;
95 clc;
96
97 % Import data
98 data = readtable('Spot+DecFutures.xlsx');
99 data=data(~any(ismissing(data.Spot),2),:);
100 data(584:585,:) = [];
101 data = table2timetable(data);
102
103 %Creating logs:
104 data.Spot = log(data.Spot);
105 data.Fut19 = log(data.Fut19);
106 data.Fut18 = log(data.Fut18);
107 data.Fut17 = log(data.Fut17);
108 data.Fut16 = log(data.Fut16);
109 data.Fut15 = log(data.Fut15);
110 data.Fut14 = log(data.Fut14);
111 data.Electricity = log(data.Electricity);
112 data.Elec = data.Electricity;
113 data.Coal = log(data.Coal);
114 data.DAX = log(data.DAX);
115 data.NaturalGAS = log(data.NaturalGAS);
116 data.Ngas = data.NaturalGAS;
117
118 % Create a time series containing first differences
119 data.Spot_firstdiff = data.Spot - lagmatrix(data.Spot,1);

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120 data.Fut19_firstdiff = data.Fut19 - lagmatrix(data.Fut19,1);
121 data.Fut18_firstdiff = data.Fut18 - lagmatrix(data.Fut18,1);
122 data.Fut17_firstdiff = data.Fut17 - lagmatrix(data.Fut17,1);
123 data.Fut16_firstdiff = data.Fut16 - lagmatrix(data.Fut16,1);
124 data.Fut15_firstdiff = data.Fut15 - lagmatrix(data.Fut15,1);
125 data.Fut14_firstdiff = data.Fut14 - lagmatrix(data.Fut14,1);
126 data.Oil_fd = data.Oil - lagmatrix(data.Oil,1);
127 data.Elec_fd = data.Elec - lagmatrix(data.Elec,1);
128 data.Coal_fd = data.Coal - lagmatrix(data.Coal,1);
129 data.DAX_fd = data.DAX - lagmatrix(data.DAX,1);
130 data.Ngas_fd = data.Ngas - lagmatrix(data.Ngas,1);
131
132 % ADF Test (Unit root test) - Check each time series for stationarity
133 results = table();
134
135 i = 0:2;
136 for model = i
137     maxlag = 12;
138     ic = 'AIC';
139     alpha = [0.01; 0.05; 0.10];
140     model
141
142
143     % Spot:
144
145     % Levels
146     [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Spot,
147         model, maxlag, ic);
148     disp('Spot Levels');
149     disp(table(pval, adfstat, lags_level));
150     critval = critval(1:3);
151     reject = adfstat > critval;
152     disp(table(alpha, critval, reject));
153     if model == 0
154         results.SpotLevels(1) = adfstat;
155     end
156     if model == 1
157         results.SpotLevels(2) = adfstat;
158     end
159     if model == 2
160         results.SpotLevels(3) = adfstat;
161     end
162
163     % First differences
164     [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
165         Spot_firstdiff(2:end), model, maxlag, ic);
166     disp('Spot first differences');
167     disp(table(pval, adfstat, lags_firstdiff));
168     critval = critval(1:3);
169     reject = adfstat > critval;
170     disp(table(alpha, critval, reject));
171     if model == 0
172         results.SpotDiff(1) = adfstat;
173     end
174     if model == 1
175         results.SpotDiff(2) = adfstat;
176     end
177     if model == 2
178         results.SpotDiff(3) = adfstat;
179     end

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179
180 % Dec2019 Future
181 % Levels
182 [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Fut19
    (1:1699), model, maxlag, ic);
183 disp('Fut19 Levels');
184 disp(table(pval, adfstat, lags_level));
185 critval = critval(1:3);
186 reject = adfstat > critval;
187 disp(table(alpha, critval, reject));
188 if model == 0
189     results.Fut19Levels(1) = adfstat;
190 end
191 if model == 1
192     results.Fut19Levels(2) = adfstat;
193 end
194 if model == 2
195     results.Fut19Levels(3) = adfstat;
196 end
197
198 % First differences
199 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
    Fut19_firstdiff(2:1699), model, maxlag, ic);
200 disp('Fut19 first differences');
201 disp(table(pval, adfstat, lags_firstdiff));
202 critval = critval(1:3);
203 reject = adfstat > critval;
204 disp(table(alpha, critval, reject));
205 if model == 0
206     results.Fut19Diff(1) = adfstat;
207 end
208 if model == 1
209     results.Fut19Diff(2) = adfstat;
210 end
211 if model == 2
212     results.Fut19Diff(3) = adfstat;
213 end
214
215
216 % Dec2018 Future
217 % Levels
218 [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Fut18
    (1:1454), model, maxlag, ic);
219 disp('Fut18 Levels');
220 disp(table(pval, adfstat, lags_level));
221 critval = critval(1:3);
222 reject = adfstat > critval;
223 disp(table(alpha, critval, reject));
224 if model == 0
225     results.Fut18Levels(1) = adfstat;
226 end
227 if model == 1
228     results.Fut18Levels(2) = adfstat;
229 end
230 if model == 2
231     results.Fut18Levels(3) = adfstat;
232 end
233
234 % First differences
235 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
    Fut18_firstdiff(2:1454), model, maxlag, ic);

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236 disp('Fut18 first differences');
237 disp(table(pval, adfstat, lags_firstdiff));
238 critval = critval(1:3);
239 reject = adfstat > critval;
240 disp(table(alpha, critval, reject));
241 if model == 0
242     results.Fut18Diff(1) = adfstat;
243 end
244 if model == 1
245     results.Fut18Diff(2) = adfstat;
246 end
247 if model == 2
248     results.Fut18Diff(3) = adfstat;
249 end
250
251
252 % Dec2017 Future
253 % Levels
254 [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Fut17
    (1:1207), model, maxlag, ic);
255 disp('Fut17 Levels');
256 disp(table(pval, adfstat, lags_level));
257 critval = critval(1:3);
258 reject = adfstat > critval;
259 disp(table(alpha, critval, reject));
260 if model == 0
261     results.Fut17Levels(1) = adfstat;
262 end
263 if model == 1
264     results.Fut17Levels(2) = adfstat;
265 end
266 if model == 2
267     results.Fut17Levels(3) = adfstat;
268 end
269
270 % First differences
271 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
    Fut17_firstdiff(2:1207), model, maxlag, ic);
272 disp('Fut17 first differences');
273 disp(table(pval, adfstat, lags_firstdiff));
274 critval = critval(1:3);
275 reject = adfstat > critval;
276 disp(table(alpha, critval, reject));
277 if model == 0
278     results.Fut17Diff(1) = adfstat;
279 end
280 if model == 1
281     results.Fut17Diff(2) = adfstat;
282 end
283 if model == 2
284     results.Fut17Diff(3) = adfstat;
285 end
286
287
288 % Dec2016 Future
289 % Levels
290 [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Fut16
    (1:983), model, maxlag, ic);
291 disp('Fut16 Levels');
292 disp(table(pval, adfstat, lags_level));
293 critval = critval(1:3);

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294     reject = adfstat > critval;
295     disp(table(alpha, critval, reject));
296     if model == 0
297         results.Fut16Levels(1) = adfstat;
298     end
299     if model == 1
300         results.Fut16Levels(2) = adfstat;
301     end
302     if model == 2
303         results.Fut16Levels(3) = adfstat;
304     end
305
306     % First differences
307     [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
308         Fut16_firstdiff(2:983), model, maxlag, ic);
309     disp('Fut16 first differences');
310     disp(table(pval, adfstat, lags_firstdiff));
311     critval = critval(1:3);
312     reject = adfstat > critval;
313     disp(table(alpha, critval, reject));
314     if model == 0
315         results.Fut16Diff(1) = adfstat;
316     end
317     if model == 1
318         results.Fut16Diff(2) = adfstat;
319     end
320     if model == 2
321         results.Fut16Diff(3) = adfstat;
322     end
323
324     % Dec2015 Future
325     % Levels
326     [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Fut15
327         (1:729), model, maxlag, ic);
328     disp('Fut15 Levels');
329     disp(table(pval, adfstat, lags_level));
330     critval = critval(1:3);
331     reject = adfstat > critval;
332     disp(table(alpha, critval, reject));
333     if model == 0
334         results.Fut15Levels(1) = adfstat;
335     end
336     if model == 1
337         results.Fut15Levels(2) = adfstat;
338     end
339     if model == 2
340         results.Fut15Levels(3) = adfstat;
341     end
342
343     % First differences
344     [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
345         Fut15_firstdiff(2:729), model, maxlag, ic);
346     disp('Fut15 first differences');
347     disp(table(pval, adfstat, lags_firstdiff));
348     critval = critval(1:3);
349     reject = adfstat > critval;
350     disp(table(alpha, critval, reject));
351     if model == 0
352         results.Fut15Diff(1) = adfstat;
353     end
354     if model == 1

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352         results.Fut15Diff(2) = adfstat;
353     end
354     if model == 2
355         results.Fut15Diff(3) = adfstat;
356     end
357
358     % Dec2014 Future
359     % Levels
360     [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Fut14
361         (1:485), model, maxlag, ic);
362     disp('Fut14 Levels');
363     disp(table(pval, adfstat, lags_level));
364     critval = critval(1:3);
365     reject = adfstat > critval;
366     disp(table(alpha, critval, reject));
367     if model == 0
368         results.Fut14Levels(1) = adfstat;
369     end
370     if model == 1
371         results.Fut14Levels(2) = adfstat;
372     end
373     if model == 2
374         results.Fut14Levels(3) = adfstat;
375     end
376
377     % First differences
378     [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
379         Fut14_firstdiff(2:485), model, maxlag, ic);
380     disp('Fut14 first differences');
381     disp(table(pval, adfstat, lags_firstdiff));
382     critval = critval(1:3);
383     reject = adfstat > critval;
384     disp(table(alpha, critval, reject));
385     if model == 0
386         results.Fut14Diff(1) = adfstat;
387     end
388     if model == 1
389         results.Fut14Diff(2) = adfstat;
390     end
391     if model == 2
392         results.Fut14Diff(3) = adfstat;
393     end
394
395     % Oil:
396     % Levels
397     [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Oil,
398         model, maxlag, ic);
399     disp('Oil Levels');
400     disp(table(pval, adfstat, lags_level));
401     critval = critval(1:3);
402     reject = adfstat > critval;
403     disp(table(alpha, critval, reject));
404     if model == 0
405         results.OilLevels(1) = adfstat;
406     end
407     if model == 1
408         results.OilLevels(2) = adfstat;
409     end
410     if model == 2
411         results.OilLevels(3) = adfstat;
412     end

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410
411
412 % First differences
413 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
      Oil_fd(2:end), model, maxlag, ic);
414 disp('Oil first differences');
415 disp(table(pval, adfstat, lags_firstdiff));
416 critval = critval(1:3);
417 reject = adfstat > critval;
418 disp(table(alpha, critval, reject));
419 if model == 0
420     results.OilDiff(1) = adfstat;
421 end
422 if model == 1
423     results.OilDiff(2) = adfstat;
424 end
425 if model == 2
426     results.OilDiff(3) = adfstat;
427 end
428
429 % Elec:
430 % Levels
431 [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Elec,
      model, maxlag, ic);
432 disp('Elec Levels');
433 disp(table(pval, adfstat, lags_level));
434 critval = critval(1:3);
435 reject = adfstat > critval;
436 disp(table(alpha, critval, reject));
437 if model == 0
438     results.ElecLevels(1) = adfstat;
439 end
440 if model == 1
441     results.ElecLevels(2) = adfstat;
442 end
443 if model == 2
444     results.ElecLevels(3) = adfstat;
445 end
446
447 % First differences
448 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
      Elec_fd(2:end), model, maxlag, ic);
449 disp('Elec first differences');
450 disp(table(pval, adfstat, lags_firstdiff));
451 critval = critval(1:3);
452 reject = adfstat > critval;
453 disp(table(alpha, critval, reject));
454 if model == 0
455     results.ElecDiff(1) = adfstat;
456 end
457 if model == 1
458     results.ElecDiff(2) = adfstat;
459 end
460 if model == 2
461     results.ElecDiff(3) = adfstat;
462 end
463
464
465 % Coal:
466 % Levels
467 [adfstat, pval, critval, ~, lags_level] = augdfautolag(data.Coal(557:

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    end), model, maxlag, ic);
468 disp('Coal Levels');
469 disp(table(pval, adfstat, lags_level));
470 critval = critval(1:3);
471 reject = adfstat > critval;
472 disp(table(alpha, critval, reject));
473 if model == 0
474     results.CoalLevels(1) = adfstat;
475 end
476 if model == 1
477     results.CoalLevels(2) = adfstat;
478 end
479 if model == 2
480     results.CoalLevels(3) = adfstat;
481 end
482
483 % First differences
484 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(data.
    Coal_fd(558:end), model, maxlag, ic);
485 disp('Coal first differences');
486 disp(table(pval, adfstat, lags_firstdiff));
487 critval = critval(1:3);
488 reject = adfstat > critval;
489 disp(table(alpha, critval, reject));
490 if model == 0
491     results.CoalDiff(1) = adfstat;
492 end
493 if model == 1
494     results.CoalDiff(2) = adfstat;
495 end
496 if model == 2
497     results.CoalDiff(3) = adfstat;
498 end
499
500 % DAX:
501 % DAX data:
502 DAXdata = table();
503 DAXdata.DAX = data.DAX;
504 DAXdata.DAX_fd = data.DAX_fd;
505 DAXdata=DAXdata(~any(ismissing(DAXdata.DAX),2),:);
506 DAXdata=DAXdata(~any(ismissing(DAXdata.DAX_fd),2),:);
507
508 % Levels
509 [adfstat, pval, critval, ~, lags_level] = augdfautolag(DAXdata.DAX(1:
    end), model, maxlag, ic);
510 disp('DAX Levels');
511 disp(table(pval, adfstat, lags_level));
512 critval = critval(1:3);
513 reject = adfstat > critval;
514 disp(table(alpha, critval, reject));
515 if model == 0
516     results.DAXLevels(1) = adfstat;
517 end
518 if model == 1
519     results.DAXLevels(2) = adfstat;
520 end
521 if model == 2
522     results.DAXLevels(3) = adfstat;
523 end
524
525 % First differences

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526 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(DAXdata.
      DAX_fd(1:end), model, maxlag, ic);
527 disp('DAX first differences');
528 disp(table(pval, adfstat, lags_firstdiff));
529 critval = critval(1:3);
530 reject = adfstat > critval;
531 disp(table(alpha, critval, reject));
532 if model == 0
533     results.DAXDiff(1) = adfstat;
534 end
535 if model == 1
536     results.DAXDiff(2) = adfstat;
537 end
538 if model == 2
539     results.DAXDiff(3) = adfstat;
540 end
541
542 % Ngas:
543 % Ngas data:
544 Ngasdata = table();
545 Ngasdata.Ngas = data.Ngas;
546 Ngasdata.Ngas_fd = data.Ngas_fd;
547 Ngasdata=Ngasdata(~any(ismissing(Ngasdata.Ngas),2),:);
548 Ngasdata=Ngasdata(~any(ismissing(Ngasdata.Ngas_fd),2),:);
549
550 % Levels
551 [adfstat, pval, critval, ~, lags_level] = augdfautolag(Ngasdata.Ngas
      (1:end), model, maxlag, ic);
552 disp('Ngas Levels');
553 disp(table(pval, adfstat, lags_level));
554 critval = critval(1:3);
555 reject = adfstat > critval;
556 disp(table(alpha, critval, reject));
557 if model == 0
558     results.NgasLevels(1) = adfstat;
559 end
560 if model == 1
561     results.NgasLevels(2) = adfstat;
562 end
563 if model == 2
564     results.NgasLevels(3) = adfstat;
565 end
566
567 % First differences
568 [adfstat, pval, critval, ~, lags_firstdiff] = augdfautolag(Ngasdata.
      Ngas_fd(1:end), model, maxlag, ic);
569 disp('Ngas first differences');
570 disp(table(pval, adfstat, lags_firstdiff));
571 critval = critval(1:3);
572 reject = adfstat > critval;
573 disp(table(alpha, critval, reject));
574 if model == 0
575     results.NgasDiff(1) = adfstat;
576 end
577 if model == 1
578     results.NgasDiff(2) = adfstat;
579 end
580 if model == 2
581     results.NgasDiff(3) = adfstat;
582 end
583 end

```

```

584 %% Part 3 – Cointegration (Johansen test):
585 clear;
586 clc;
587
588 % Import data and create variables:
589 data = readtable('Spot+DecFutures.xlsx');
590 data=data(~any(ismissing(data.Spot),2),:);
591 data(584:585,:) = [];
592 data = table2timetable(data);
593 data.Spot = log(data.Spot);
594 data.Fut19 = log(data.Fut19);
595 data.Fut18 = log(data.Fut18);
596 data.Fut17 = log(data.Fut17);
597 data.Fut16 = log(data.Fut16);
598 data.Fut15 = log(data.Fut15);
599 data.Fut14 = log(data.Fut14);
600
601 % Determining lag levels:
602 % Spot and Fut19:
603 reg1 = table();
604 reg1.Spot = data.Spot;
605 reg1.Fut19 = data.Fut19;
606 reg1(1700:end,:) = [];
607 reg1 = reg1{:,:};
608 [laglength, AIC, logL] = VARlag(reg1,12)
609 %Optimal = 12
610
611 % Spot and Fut18:
612 reg2 = table();
613 reg2.Spot = data.Spot;
614 reg2.Fut18 = data.Fut18;
615 reg2(1455:end,:) = [];
616 reg2 = reg2{:,:};
617 [laglength, AIC, logL] = VARlag(reg2,12)
618 %Optimal = 8
619
620 % Spot and Fut17:
621 reg3 = table();
622 reg3.Spot = data.Spot;
623 reg3.Fut17 = data.Fut17;
624 reg3(1208:end,:) = [];
625 reg3 = reg3{:,:};
626 [laglength, AIC, logL] = VARlag(reg3,12)
627 %Optimal = 12
628
629 %Spot and Fut16
630 reg4 = table();
631 reg4.Spot = data.Spot;
632 reg4.Fut16 = data.Fut16;
633 reg4(984:end,:) = [];
634 reg4 = reg4{:,:};
635 [laglength, AIC, logL] = VARlag(reg4,12)
636 %Optimal = 7
637
638 % Spot and Fut15
639 reg5 = table();
640 reg5.Spot = data.Spot;
641 reg5.Fut15 = data.Fut15;
642 reg5(730:end,:) = [];
643 reg5 = reg5{:,:};
644 [laglength, AIC, logL] = VARlag(reg5,12)

```

```

645 %Optimal = 10
646
647 %Spot and Fut14
648 reg6 = table();
649 reg6.Spot = data.Spot;
650 reg6.Fut14 = data.Fut14;
651 reg6(486:end,:) = [];
652 reg6 = reg6{:,:};
653 [laglength, AIC, logL] = VARlag(reg6,12)
654 %Optimal = 7
655
656 %Tables for results:
657 traceH0 = table();
658 MaxEigH0 = table();
659 traceH1 = table();
660 MaxEigH1 = table();
661
662 % Spot and Fut19:
663 % Null hypothesis – cointegrated series with intercept but no trend
664 [~,pValue,~,~,~] = jcitest(reg1, 'model', 'H1*', 'lags', 12, 'test', '
        trace', 'display', 'off');
665 disp('trace H0');
666 disp(pValue);
667 traceH0.Fut19(1) = pValue.r0;
668 traceH0.Fut19(2) = pValue.r1;
669
670 [~,pValue,~,~,~] = jcitest(reg1, 'model', 'H1*', 'lags', 12, 'test', '
        maxeig', 'display', 'off');
671 disp('max eigenvector H0');
672 disp(pValue);
673 MaxEigH0.Fut19(1) = pValue.r0;
674 MaxEigH0.Fut19(2) = pValue.r1;
675
676 % Null hypothesis – cointegrated series with no intercept, no trend
677 [~,pValue,~,~,~] = jcitest(reg1, 'model', 'H2', 'lags', 12, 'test', 'trace
        ', 'display', 'off');
678 disp('trace H1');
679 disp(pValue)
680 traceH1.Fut19(1) = pValue.r0;
681 traceH1.Fut19(2) = pValue.r1;
682
683 [~,pValue,~,~,~] = jcitest(reg1, 'model', 'H2', 'lags', 12, 'test', '
        maxeig', 'display', 'off');
684 disp('max eigenvector H1');
685 disp(pValue);
686 MaxEigH1.Fut19(1) = pValue.r0;
687 MaxEigH1.Fut19(2) = pValue.r1;
688
689 % Spot and Fut18:
690 % Null hypothesis – cointegrated series with intercept but no trend
691 [~,pValue,~,~,~] = jcitest(reg2, 'model', 'H1*', 'lags', 8, 'test', 'trace
        ', 'display', 'off');
692 disp('trace H0');
693 disp(pValue);
694 traceH0.Fut18(1) = pValue.r0;
695 traceH0.Fut18(2) = pValue.r1;
696
697 [~,pValue,~,~,~] = jcitest(reg2, 'model', 'H1*', 'lags', 8, 'test', '
        maxeig', 'display', 'off');
698 disp('max eigenvector H0');
699 disp(pValue);

```

```

700 MaxEigH0.Fut18(1) = pValue.r0;
701 MaxEigH0.Fut18(2) = pValue.r1;
702
703 % Null hypothesis – cointegrated series with no intercept, no trend
704 [~,pValue,~,~,~] = jcitest(reg2, 'model', 'H2', 'lags', 8, 'test', 'trace'
    , 'display', 'off');
705 disp('trace H1');
706 disp(pValue);
707 traceH1.Fut18(1) = pValue.r0;
708 traceH1.Fut18(2) = pValue.r1;
709
710 [~,pValue,~,~,~] = jcitest(reg2, 'model', 'H2', 'lags', 8, 'test', 'maxeig'
    , 'display', 'off');
711 disp('max eigenvector H1');
712 disp(pValue);
713 MaxEigH1.Fut18(1) = pValue.r0;
714 MaxEigH1.Fut18(2) = pValue.r1;
715
716 % Spot and Fut17:
717 % Null hypothesis – cointegrated series with intercept but no trend
718 [~,pValue,~,~,~] = jcitest(reg3, 'model', 'H1*', 'lags', 12, 'test', '
    trace', 'display', 'off');
719 disp('trace H0');
720 disp(pValue);
721 traceH0.Fut17(1) = pValue.r0;
722 traceH0.Fut17(2) = pValue.r1;
723
724 [~,pValue,~,~,~] = jcitest(reg3, 'model', 'H1*', 'lags', 12, 'test', '
    maxeig', 'display', 'off');
725 disp('max eigenvector H0');
726 disp(pValue);
727 MaxEigH0.Fut17(1) = pValue.r0;
728 MaxEigH0.Fut17(2) = pValue.r1;
729
730 % Null hypothesis – cointegrated series with no intercept, no trend
731 [~,pValue,~,~,~] = jcitest(reg3, 'model', 'H2', 'lags', 12, 'test', 'trace'
    , 'display', 'off');
732 disp('trace H1');
733 disp(pValue);
734 traceH1.Fut17(1) = pValue.r0;
735 traceH1.Fut17(2) = pValue.r1;
736
737 [~,pValue,~,~,~] = jcitest(reg3, 'model', 'H2', 'lags', 12, 'test', '
    maxeig', 'display', 'off');
738 disp('max eigenvector H1');
739 disp(pValue);
740 MaxEigH1.Fut17(1) = pValue.r0;
741 MaxEigH1.Fut17(2) = pValue.r1;
742
743 % Spot and Fut16:
744 % Null hypothesis – cointegrated series with intercept but no trend
745 [~,pValue,~,~,~] = jcitest(reg4, 'model', 'H1*', 'lags', 7, 'test', 'trace'
    , 'display', 'off');
746 disp('trace H0');
747 disp(pValue);
748 traceH0.Fut16(1) = pValue.r0;
749 traceH0.Fut16(2) = pValue.r1;
750
751 [~,pValue,~,~,~] = jcitest(reg4, 'model', 'H1*', 'lags', 7, 'test', '
    maxeig', 'display', 'off');
752 disp('max eigenvector H0');

```

```

753 disp(pValue);
754 MaxEigH0.Fut16(1) = pValue.r0;
755 MaxEigH0.Fut16(2) = pValue.r1;
756
757 % Null hypothesis – cointegrated series with no intercept, no trend
758 [~,pValue,~,~,~] = jcitest(reg4, 'model', 'H2', 'lags', 7, 'test', 'trace'
, 'display', 'off');
759 disp('trace H1');
760 disp(pValue);
761 traceH1.Fut16(1) = pValue.r0;
762 traceH1.Fut16(2) = pValue.r1;
763
764 [~,pValue,~,~,~] = jcitest(reg4, 'model', 'H2', 'lags', 7, 'test', 'maxeig'
, 'display', 'off');
765 disp('max eigenvector H1');
766 disp(pValue);
767 MaxEigH1.Fut16(1) = pValue.r0;
768 MaxEigH1.Fut16(2) = pValue.r1;
769
770 % Spot and Fut15:
771 % Null hypothesis – cointegrated series with intercept but no trend
772 [~,pValue,~,~,~] = jcitest(reg5, 'model', 'H1*', 'lags', 10, 'test', '
trace', 'display', 'off');
773 disp('trace H0');
774 disp(pValue);
775 traceH0.Fut15(1) = pValue.r0;
776 traceH0.Fut15(2) = pValue.r1;
777
778 [~,pValue,~,~,~] = jcitest(reg5, 'model', 'H1*', 'lags', 10, 'test', '
maxeig', 'display', 'off');
779 disp('max eigenvector H0');
780 disp(pValue);
781 MaxEigH0.Fut15(1) = pValue.r0;
782 MaxEigH0.Fut15(2) = pValue.r1;
783
784 % Null hypothesis – cointegrated series with no intercept, no trend
785 [~,pValue,~,~,~] = jcitest(reg5, 'model', 'H2', 'lags', 10, 'test', 'trace'
, 'display', 'off');
786 disp('trace H1');
787 disp(pValue);
788 traceH1.Fut15(1) = pValue.r0;
789 traceH1.Fut15(2) = pValue.r1;
790
791 [~,pValue,~,~,~] = jcitest(reg5, 'model', 'H2', 'lags', 10, 'test', '
maxeig', 'display', 'off');
792 disp('max eigenvector H1');
793 disp(pValue);
794 MaxEigH1.Fut15(1) = pValue.r0;
795 MaxEigH1.Fut15(2) = pValue.r1;
796
797 % Spot and Fut14:
798 % Null hypothesis – cointegrated series with intercept but no trend
799 [~,pValue,~,~,~] = jcitest(reg6, 'model', 'H1*', 'lags', 7, 'test', 'trace'
, 'display', 'off');
800 disp('trace H0');
801 disp(pValue);
802 traceH0.Fut14(1) = pValue.r0;
803 traceH0.Fut14(2) = pValue.r1;
804
805 [~,pValue,~,~,~] = jcitest(reg6, 'model', 'H1*', 'lags', 7, 'test', '
maxeig', 'display', 'off');

```

```

806 disp('max eigenvector H0');
807 disp(pValue);
808 MaxEigH0.Fut14(1) = pValue.r0;
809 MaxEigH0.Fut14(2) = pValue.r1;
810
811 % Null hypothesis – cointegrated series with no intercept, no trend
812 [~,pValue,~,~,~] = jcitest(reg6, 'model', 'H2', 'lags', 7, 'test', 'trace'
    , 'display', 'off');
813 disp('trace H1');
814 disp(pValue);
815 traceH1.Fut14(1) = pValue.r0;
816 traceH1.Fut14(2) = pValue.r1;
817
818 [~,pValue,~,~,~] = jcitest(reg6, 'model', 'H2', 'lags', 7, 'test', 'maxeig'
    , 'display', 'off');
819 disp('max eigenvector H1');
820 disp(pValue);
821 MaxEigH1.Fut14(1) = pValue.r0;
822 MaxEigH1.Fut14(2) = pValue.r1;
823
824 %% Part 4 – ECM and ECM-GARCH:
825 clear;
826 clc;
827
828 % Import data and create variables:
829 data = readtable('Spot+DecFutures.xlsx');
830 data=data(~any(ismissing(data.Spot),2),:);
831 data(584:585,:) = [];
832 data = table2timetable(data);
833 data.Spot = log(data.Spot);
834 data.Fut19 = log(data.Fut19);
835 data.Fut18 = log(data.Fut18);
836 data.Fut17 = log(data.Fut17);
837 data.Fut16 = log(data.Fut16);
838 data.Fut15 = log(data.Fut15);
839 data.Fut14 = log(data.Fut14);
840
841 % Creating first differences:
842 data.Spot_firstdiff = data.Spot - lagmatrix(data.Spot,1);
843 data.Fut19_firstdiff = data.Fut19 - lagmatrix(data.Fut19,1);
844 data.Fut18_firstdiff = data.Fut18 - lagmatrix(data.Fut18,1);
845 data.Fut17_firstdiff = data.Fut17 - lagmatrix(data.Fut17,1);
846 data.Fut16_firstdiff = data.Fut16 - lagmatrix(data.Fut16,1);
847 data.Fut15_firstdiff = data.Fut15 - lagmatrix(data.Fut15,1);
848 data.Fut14_firstdiff = data.Fut14 - lagmatrix(data.Fut14,1);
849
850 % Finding residuals between Spot and lagged Fut19:
851 reg1 = table();
852 reg1.Date = data.Date;
853 reg1.Spot = data.Spot;
854 reg1.LagFut19 = lagmatrix(data.Fut19,1);
855 reg1(1,:) = [];
856 reg1(1700:end,:) = [];
857 modell = fitlm(reg1, 'Spot ~ LagFut19')
858 reg1.residuals1 = modell.Residuals.Raw;
859 figure;
860 plot(reg1.Date, reg1.residuals1);
861
862 % Defining ECM variables – Spot and Fut19:
863 ECM1 = table();
864 ECM1.Date = reg1.Date;

```

```

865 ECM1.Spot_firstdiff = data.Spot_firstdiff(2:1700);
866 ECM1.LaggedResiduals = lagmatrix(reg1.residuals1,1);
867 %Lag variables - Fut:
868 ECM1.Fut19_firstdiff_lag1 = reg1.LagFut19 - lagmatrix(reg1.LagFut19,1);
869 ECM1.Fut19_firstdiff_lag2 = lagmatrix(ECM1.Fut19_firstdiff_lag1,1);
870 ECM1.Fut19_firstdiff_lag3 = lagmatrix(ECM1.Fut19_firstdiff_lag1,2);
871 ECM1.Fut19_firstdiff_lag4 = lagmatrix(ECM1.Fut19_firstdiff_lag1,3);
872 ECM1.Fut19_firstdiff_lag5 = lagmatrix(ECM1.Fut19_firstdiff_lag1,4);
873 ECM1.Fut19_firstdiff_lag6 = lagmatrix(ECM1.Fut19_firstdiff_lag1,5);
874 ECM1.Fut19_firstdiff_lag7 = lagmatrix(ECM1.Fut19_firstdiff_lag1,6);
875 ECM1.Fut19_firstdiff_lag8 = lagmatrix(ECM1.Fut19_firstdiff_lag1,7);
876 ECM1.Fut19_firstdiff_lag9 = lagmatrix(ECM1.Fut19_firstdiff_lag1,8);
877 ECM1.Fut19_firstdiff_lag10 = lagmatrix(ECM1.Fut19_firstdiff_lag1,9);
878 ECM1.Fut19_firstdiff_lag11 = lagmatrix(ECM1.Fut19_firstdiff_lag1,10);
879 ECM1.Fut19_firstdiff_lag12 = lagmatrix(ECM1.Fut19_firstdiff_lag1,11);
880 %Lag variables spot:
881 ECM1.Spot_firstdiff_lag1 = lagmatrix(ECM1.Spot_firstdiff,1);
882 ECM1.Spot_firstdiff_lag2 = lagmatrix(ECM1.Spot_firstdiff,2);
883 ECM1.Spot_firstdiff_lag3 = lagmatrix(ECM1.Spot_firstdiff,3);
884 ECM1.Spot_firstdiff_lag4 = lagmatrix(ECM1.Spot_firstdiff,4);
885 ECM1.Spot_firstdiff_lag5 = lagmatrix(ECM1.Spot_firstdiff,5);
886 ECM1.Spot_firstdiff_lag6 = lagmatrix(ECM1.Spot_firstdiff,6);
887 ECM1.Spot_firstdiff_lag7 = lagmatrix(ECM1.Spot_firstdiff,7);
888 ECM1.Spot_firstdiff_lag8 = lagmatrix(ECM1.Spot_firstdiff,8);
889 ECM1.Spot_firstdiff_lag9 = lagmatrix(ECM1.Spot_firstdiff,9);
890 ECM1.Spot_firstdiff_lag10 = lagmatrix(ECM1.Spot_firstdiff,10);
891 ECM1.Spot_firstdiff_lag11 = lagmatrix(ECM1.Spot_firstdiff,11);
892 ECM1.Spot_firstdiff_lag12 = lagmatrix(ECM1.Spot_firstdiff,12);
893
894 ECM1 = fitlm(ECM1, ['Spot_firstdiff ~ LaggedResiduals +
      Fut19_firstdiff_lag1 + Fut19_firstdiff_lag2' ...
895      '+ Fut19_firstdiff_lag3 + Fut19_firstdiff_lag4 + Fut19_firstdiff_lag5
      + Fut19_firstdiff_lag6' ...
896      '+ Fut19_firstdiff_lag7 + Fut19_firstdiff_lag8 + Fut19_firstdiff_lag9
      + Fut19_firstdiff_lag10' ...
897      '+ Fut19_firstdiff_lag11 + Fut19_firstdiff_lag12 +
      Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
898      '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
      Spot_firstdiff_lag6' ...
899      '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
      Spot_firstdiff_lag10' ...
900      '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12'])
901
902 % Engle's ARCH Test for ECMF19:
903 ECM1.SqResiduals = (ECM1.Residuals.Raw).^2;
904 ECM1.res1 = lagmatrix(ECM1.SqResiduals,1);
905 ECM1.res2 = lagmatrix(ECM1.SqResiduals,2);
906 ECM1.res3 = lagmatrix(ECM1.SqResiduals,3);
907 ECM1.res4 = lagmatrix(ECM1.SqResiduals,4);
908 ECM1.res5 = lagmatrix(ECM1.SqResiduals,5);
909 ECM1.res6 = lagmatrix(ECM1.SqResiduals,6);
910 ECM1.res7 = lagmatrix(ECM1.SqResiduals,7);
911 ECM1.res8 = lagmatrix(ECM1.SqResiduals,8);
912 ECM1.res9 = lagmatrix(ECM1.SqResiduals,9);
913 ECM1.res10 = lagmatrix(ECM1.SqResiduals,10);
914 ECM1.res11 = lagmatrix(ECM1.SqResiduals,11);
915 ECM1.res12 = lagmatrix(ECM1.SqResiduals,12);
916
917 ECM1 = fillmissing(ECM1, 'constant', 0, 'DataVariables', ...
918      {'res1', 'res2', 'res3', 'res4', 'res5', 'res6', 'res7',
      ...

```



```

919         'res8', 'res9', 'res10', 'res11', 'res12'}));
920
921 % Running the auxiliary regression
922 AuxReg1 = fitlm(ECM1, ['SqResiduals ~ res1 + res2 + res3 + res3 + res4 +
923     res5' ...
924     '+ res6 + res7 + res8 + res9 + res10 + res11 + res12'])
925 % Testing for autocorrelation:
926 T = 1687;
927 alpha = [0.1, 0.05, 0.01]
928 TestStatARCH = (T)*AuxReg1.Rsquared.Ordinary
929 pVal = 1 - cdf('Chisquare', TestStatARCH, 12)
930 criticalARCH = chi2inv(1-alpha, 12);
931 rejection = TestStatARCH > criticalARCH
932
933 % ECM-GARCH: Spot and Fut19:
934 GARCH1 = garch('GARCHlags', 1, 'ARCHlags', 1)
935 [estMdl, estParamCov, logL] = estimate(GARCH1, ECM1.Spot_firstdiff)
936 condVar = infer(estMdl, ECM1.Spot_firstdiff);
937 ECM1.condVol = sqrt(condVar);
938
939 ECM.GARCH1 = fitlm(ECM1, ['Spot_firstdiff ~ LaggedResiduals +
940     Fut19_firstdiff_lag1 + Fut19_firstdiff_lag2' ...
941     '+ Fut19_firstdiff_lag3 + Fut19_firstdiff_lag4 + Fut19_firstdiff_lag5
942     + Fut19_firstdiff_lag6' ...
943     '+ Fut19_firstdiff_lag7 + Fut19_firstdiff_lag8 + Fut19_firstdiff_lag9
944     + Fut19_firstdiff_lag10' ...
945     '+ Fut19_firstdiff_lag11 + Fut19_firstdiff_lag12 +
946     Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
947     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
948     Spot_firstdiff_lag6' ...
949     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
950     Spot_firstdiff_lag10' ...
951     '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12 + condVol'])
952
953 figure;
954 plot(ECM1.Date, ECM1.Spot_firstdiff);
955 hold on;
956 plot(ECM1.Date, ECM1.condVol);
957 hold off;
958 legend('Log-differenced spot price', 'Inferred volatility');
959 box('off');
960
961 % Finding residuals between Spot and lagged Fut18:
962 reg2 = table();
963 reg2.Date = data.Date;
964 reg2.Spot = data.Spot;
965 reg2.LagFut18 = lagmatrix(data.Fut18,1);
966 reg2(1,:) = [];
967 reg2(1455:end,:) = [];
968 model2 = fitlm(reg2, 'Spot ~ LagFut18')
969 reg2.residuals = model2.Residuals.Raw;
970 plot(reg2.Date, reg2.residuals)
971
972 % Defining ECM variables – Spot and Fut18:
973 ECM2 = table();
974 ECM2.Date = reg2.Date;
975 ECM2.Spot_firstdiff = data.Spot_firstdiff(2:1455);
976 ECM2.LaggedResiduals = lagmatrix(reg2.residuals,1);
977 %Lag variables – Fut:
978 ECM2.Fut18_firstdiff_lag1 = reg2.LagFut18 - lagmatrix(reg2.LagFut18,1);

```

```

973 ECM2.Fut18_firstdiff_lag2 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,1);
974 ECM2.Fut18_firstdiff_lag3 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,2);
975 ECM2.Fut18_firstdiff_lag4 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,3);
976 ECM2.Fut18_firstdiff_lag5 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,4);
977 ECM2.Fut18_firstdiff_lag6 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,5);
978 ECM2.Fut18_firstdiff_lag7 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,6);
979 ECM2.Fut18_firstdiff_lag8 = lagmatrix(ECM2.Fut18_firstdiff_lag1 ,7);
980 %Lag variables spot:
981 ECM2.Spot_firstdiff_lag1 = lagmatrix(ECM2.Spot_firstdiff ,1);
982 ECM2.Spot_firstdiff_lag2 = lagmatrix(ECM2.Spot_firstdiff ,2);
983 ECM2.Spot_firstdiff_lag3 = lagmatrix(ECM2.Spot_firstdiff ,3);
984 ECM2.Spot_firstdiff_lag4 = lagmatrix(ECM2.Spot_firstdiff ,4);
985 ECM2.Spot_firstdiff_lag5 = lagmatrix(ECM2.Spot_firstdiff ,5);
986 ECM2.Spot_firstdiff_lag6 = lagmatrix(ECM2.Spot_firstdiff ,6);
987 ECM2.Spot_firstdiff_lag7 = lagmatrix(ECM2.Spot_firstdiff ,7);
988 ECM2.Spot_firstdiff_lag8 = lagmatrix(ECM2.Spot_firstdiff ,8);
989
990
991 ECM2 = fitlm(ECM2, [ 'Spot_firstdiff ~ LaggedResiduals +
    Fut18_firstdiff_lag1 + Fut18_firstdiff_lag2' ...
992     '+ Fut18_firstdiff_lag3 + Fut18_firstdiff_lag4 + Fut18_firstdiff_lag5
    + Fut18_firstdiff_lag6' ...
993     '+ Fut18_firstdiff_lag7 + Fut18_firstdiff_lag8 + Spot_firstdiff_lag1
    + Spot_firstdiff_lag2' ...
994     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
995     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8' ])
996
997 % Engle's ARCH test - Spot and Fut18:
998 ECM2.SqResiduals = (ECM2.Residuals.Raw).^2;
999 ECM2.res1 = lagmatrix(ECM2.SqResiduals ,1);
1000 ECM2.res2 = lagmatrix(ECM2.SqResiduals ,2);
1001 ECM2.res3 = lagmatrix(ECM2.SqResiduals ,3);
1002 ECM2.res4 = lagmatrix(ECM2.SqResiduals ,4);
1003 ECM2.res5 = lagmatrix(ECM2.SqResiduals ,5);
1004 ECM2.res6 = lagmatrix(ECM2.SqResiduals ,6);
1005 ECM2.res7 = lagmatrix(ECM2.SqResiduals ,7);
1006 ECM2.res8 = lagmatrix(ECM2.SqResiduals ,8);
1007 ECM2.res9 = lagmatrix(ECM2.SqResiduals ,9);
1008 ECM2.res10 = lagmatrix(ECM2.SqResiduals ,10);
1009 ECM2.res11 = lagmatrix(ECM2.SqResiduals ,11);
1010 ECM2.res12 = lagmatrix(ECM2.SqResiduals ,12);
1011
1012 ECM2 = fillmissing(ECM2, 'constant', 0, 'DataVariables', ...
1013     { 'res1', 'res2', 'res3', 'res4', 'res5', 'res6', 'res7',
    ...
    'res8', 'res9', 'res10', 'res11', 'res12' });
1014
1015
1016 % Running the auxiliary regression
1017 AuxReg2 = fitlm(ECM2, [ 'SqResiduals ~ res1 + res2 + res3 + res3 + res4 +
    res5' ...
1018     '+ res6 + res7 + res8 + res9 + res10 + res11 + res12' ])
1019
1020 % Testing for autocorrelation:
1021 T = 1446;
1022 alpha = [0.1, 0.05, 0.01]
1023 TestStatARCH = (T)*AuxReg2.Rsquared.Ordinary
1024 pVal = 1 - cdf('Chisquare', TestStatARCH, 12)
1025 criticalARCH = chi2inv(1-alpha, 12);
1026 rejection = TestStatARCH > criticalARCH
1027

```

```

1028 % ECM-GARCH: Spot and Fut18:
1029 GARCH2 = garch('GARCHlags', 1, 'ARCHlags', 1)
1030 [estMdl, estParamCov, logL] = estimate(GARCH2, ECM2.Spot_firstdiff)
1031 condVar = infer(estMdl, ECM2.Spot_firstdiff);
1032 ECM2.condVol = sqrt(condVar);
1033
1034 ECM_GARCH2 = fitlm(ECM2, ['Spot_firstdiff ~ LaggedResiduals +
    Fut18_firstdiff_lag1 + Fut18_firstdiff_lag2' ...
1035     '+ Fut18_firstdiff_lag3 + Fut18_firstdiff_lag4 + Fut18_firstdiff_lag5
        + Fut18_firstdiff_lag6' ...
1036     '+ Fut18_firstdiff_lag7 + Fut18_firstdiff_lag8 + Spot_firstdiff_lag1
        + Spot_firstdiff_lag2' ...
1037     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
        Spot_firstdiff_lag6' ...
1038     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + condVol'])
1039
1040 figure;
1041 plot(ECM2.Date, ECM2.Spot_firstdiff);
1042 hold on
1043 plot(ECM2.Date, ECM2.condVol);
1044 hold off
1045 legend('Log-differenced spot price', 'Inferred volatility')
1046 box('off')
1047
1048 % Finding residuals between Spot and lagged Fut17:
1049 reg3 = table();
1050 reg3.Date = data.Date;
1051 reg3.Spot = data.Spot;
1052 reg3.LagFut17 = lagmatrix(data.Fut17,1);
1053 reg3(1,:) = [];
1054 reg3(1208:end,:) = [];
1055 model3 = fitlm(reg3, 'Spot ~ LagFut17')
1056 reg3.residuals = model3.Residuals.Raw;
1057 plot(reg3.Date, reg3.residuals)
1058
1059 % Defining ECM variables – Spot and Fut17:
1060 ECM3 = table();
1061 ECM3.Date = reg3.Date;
1062 ECM3.Spot_firstdiff = data.Spot_firstdiff(2:1208);
1063 ECM3.LaggedResiduals = lagmatrix(reg3.residuals,1);
1064 %Lag variables – Fut:
1065 ECM3.Fut17_firstdiff_lag1 = reg3.LagFut17 - lagmatrix(reg3.LagFut17,1);
1066 ECM3.Fut17_firstdiff_lag2 = lagmatrix(ECM3.Fut17_firstdiff_lag1,1);
1067 ECM3.Fut17_firstdiff_lag3 = lagmatrix(ECM3.Fut17_firstdiff_lag1,2);
1068 ECM3.Fut17_firstdiff_lag4 = lagmatrix(ECM3.Fut17_firstdiff_lag1,3);
1069 ECM3.Fut17_firstdiff_lag5 = lagmatrix(ECM3.Fut17_firstdiff_lag1,4);
1070 ECM3.Fut17_firstdiff_lag6 = lagmatrix(ECM3.Fut17_firstdiff_lag1,5);
1071 ECM3.Fut17_firstdiff_lag7 = lagmatrix(ECM3.Fut17_firstdiff_lag1,6);
1072 ECM3.Fut17_firstdiff_lag8 = lagmatrix(ECM3.Fut17_firstdiff_lag1,7);
1073 ECM3.Fut17_firstdiff_lag9 = lagmatrix(ECM3.Fut17_firstdiff_lag1,8);
1074 ECM3.Fut17_firstdiff_lag10 = lagmatrix(ECM3.Fut17_firstdiff_lag1,9);
1075 ECM3.Fut17_firstdiff_lag11 = lagmatrix(ECM3.Fut17_firstdiff_lag1,10);
1076 ECM3.Fut17_firstdiff_lag12 = lagmatrix(ECM3.Fut17_firstdiff_lag1,11);
1077
1078 %Lag variables spot:
1079 ECM3.Spot_firstdiff_lag1 = lagmatrix(ECM3.Spot_firstdiff,1);
1080 ECM3.Spot_firstdiff_lag2 = lagmatrix(ECM3.Spot_firstdiff,2);
1081 ECM3.Spot_firstdiff_lag3 = lagmatrix(ECM3.Spot_firstdiff,3);
1082 ECM3.Spot_firstdiff_lag4 = lagmatrix(ECM3.Spot_firstdiff,4);
1083 ECM3.Spot_firstdiff_lag5 = lagmatrix(ECM3.Spot_firstdiff,5);
1084 ECM3.Spot_firstdiff_lag6 = lagmatrix(ECM3.Spot_firstdiff,6);

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1085 ECM3.Spot_firstdiff_lag7 = lagmatrix(ECM3.Spot_firstdiff,7);
1086 ECM3.Spot_firstdiff_lag8 = lagmatrix(ECM3.Spot_firstdiff,8);
1087 ECM3.Spot_firstdiff_lag9 = lagmatrix(ECM3.Spot_firstdiff,9);
1088 ECM3.Spot_firstdiff_lag10 = lagmatrix(ECM3.Spot_firstdiff,10);
1089 ECM3.Spot_firstdiff_lag11 = lagmatrix(ECM3.Spot_firstdiff,11);
1090 ECM3.Spot_firstdiff_lag12 = lagmatrix(ECM3.Spot_firstdiff,12);
1091
1092
1093 ECM3 = fitlm(ECM3, ['Spot_firstdiff ~ LaggedResiduals +
    Fut17_firstdiff_lag1 + Fut17_firstdiff_lag2' ...
1094     '+ Fut17_firstdiff_lag3 + Fut17_firstdiff_lag4 + Fut17_firstdiff_lag5
        + Fut17_firstdiff_lag6' ...
1095     '+ Fut17_firstdiff_lag7 + Fut17_firstdiff_lag8 + Fut17_firstdiff_lag9
        + Fut17_firstdiff_lag10' ...
1096     '+ Fut17_firstdiff_lag11 + Fut17_firstdiff_lag12 +
        Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
1097     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
        Spot_firstdiff_lag6' ...
1098     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
        Spot_firstdiff_lag10' ...
1099     '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12'])
1100
1101 % Engle's ARCH Test - Spot and Fut17:
1102 ECM3.SqResiduals = (ECM3.Residuals.Raw).^2;
1103 ECM3.res1 = lagmatrix(ECM3.SqResiduals,1);
1104 ECM3.res2 = lagmatrix(ECM3.SqResiduals,2);
1105 ECM3.res3 = lagmatrix(ECM3.SqResiduals,3);
1106 ECM3.res4 = lagmatrix(ECM3.SqResiduals,4);
1107 ECM3.res5 = lagmatrix(ECM3.SqResiduals,5);
1108 ECM3.res6 = lagmatrix(ECM3.SqResiduals,6);
1109 ECM3.res7 = lagmatrix(ECM3.SqResiduals,7);
1110 ECM3.res8 = lagmatrix(ECM3.SqResiduals,8);
1111 ECM3.res9 = lagmatrix(ECM3.SqResiduals,9);
1112 ECM3.res10 = lagmatrix(ECM3.SqResiduals,10);
1113 ECM3.res11 = lagmatrix(ECM3.SqResiduals,11);
1114 ECM3.res12 = lagmatrix(ECM3.SqResiduals,12);
1115
1116 ECM3 = fillmissing(ECM3, 'constant', 0, 'DataVariables', ...
1117     {'res1', 'res2', 'res3', 'res4', 'res5', 'res6', 'res7',
        ...
        'res8', 'res9', 'res10', 'res11', 'res12'});
1118
1119
1120 % Running the auxiliary regression
1121 AuxReg3 = fitlm(ECM3, ['SqResiduals ~ res1 + res2 + res3 + res3 + res4 +
    res5' ...
1122     '+ res6 + res7 + res8 + res9 + res10 + res11 + res12'])
1123
1124 % Testing for autocorrelation:
1125 T = 1195;
1126 alpha = [0.1, 0.05, 0.01]
1127 TestStatARCH = (T)*AuxReg3.Rsquared.Ordinary
1128 pVal = 1 - cdf('Chisquare', TestStatARCH, 12)
1129 criticalARCH = chi2inv(1-alpha, 12);
1130 rejection = TestStatARCH > criticalARCH
1131
1132 % ECM-GARCH: Spot and Fut17:
1133 GARCH3 = garch('GARCHlags', 1, 'ARCHlags', 1)
1134 [estMdl, estParamCov, logL] = estimate(GARCH3, ECM3.Spot_firstdiff)
1135 condVar = infer(estMdl, ECM3.Spot_firstdiff);
1136 ECM3.condVol = sqrt(condVar);
1137

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1138 ECM_GARCH3 = fitlm(ECM3, ['Spot_firstdiff ~ LaggedResiduals +
    Fut17_firstdiff_lag1 + Fut17_firstdiff_lag2' ...
1139     '+ Fut17_firstdiff_lag3 + Fut17_firstdiff_lag4 + Fut17_firstdiff_lag5
        + Fut17_firstdiff_lag6' ...
1140     '+ Fut17_firstdiff_lag7 + Fut17_firstdiff_lag8 + Fut17_firstdiff_lag9
        + Fut17_firstdiff_lag10' ...
1141     '+ Fut17_firstdiff_lag11 + Fut17_firstdiff_lag12 +
        Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
1142     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
        Spot_firstdiff_lag6' ...
1143     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
        Spot_firstdiff_lag10' ...
1144     '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12 + condVol'])
1145
1146 figure;
1147 plot(ECM3.Date, ECM3.Spot_firstdiff);
1148 hold on
1149 plot(ECM3.Date, ECM3.condVol);
1150 hold off
1151 legend('Log-differenced spot price', 'Inferred volatility')
1152 box('off')
1153 xtickformat('yyyy')
1154
1155 % Finding residuals between Spot and lagged Fut16:
1156 reg4 = table();
1157 reg4.Date = data.Date;
1158 reg4.Spot = data.Spot;
1159 reg4.LagFut16 = lagmatrix(data.Fut16,1);
1160 reg4(1,:) = [];
1161 reg4(984:end,:) = [];
1162 model4 = fitlm(reg4, 'Spot ~ LagFut16')
1163 reg4.residuals = model4.Residuals.Raw;
1164 plot(reg4.Date, reg4.residuals)
1165
1166 % Defining ECM variables – Spot and Fut16:
1167 ECM4 = table();
1168 ECM4.Date = reg4.Date;
1169 ECM4.Spot_firstdiff = data.Spot_firstdiff(2:984);
1170 ECM4.LaggedResiduals = lagmatrix(reg4.residuals,1);
1171 %Lag variables – Fut:
1172 ECM4.Fut16_firstdiff_lag1 = reg4.LagFut16 – lagmatrix(reg4.LagFut16,1);
1173 ECM4.Fut16_firstdiff_lag2 = lagmatrix(ECM4.Fut16_firstdiff_lag1,1);
1174 ECM4.Fut16_firstdiff_lag3 = lagmatrix(ECM4.Fut16_firstdiff_lag1,2);
1175 ECM4.Fut16_firstdiff_lag4 = lagmatrix(ECM4.Fut16_firstdiff_lag1,3);
1176 ECM4.Fut16_firstdiff_lag5 = lagmatrix(ECM4.Fut16_firstdiff_lag1,4);
1177 ECM4.Fut16_firstdiff_lag6 = lagmatrix(ECM4.Fut16_firstdiff_lag1,5);
1178 ECM4.Fut16_firstdiff_lag7 = lagmatrix(ECM4.Fut16_firstdiff_lag1,6);
1179 %Lag variables spot:
1180 ECM4.Spot_firstdiff_lag1 = lagmatrix(ECM4.Spot_firstdiff,1);
1181 ECM4.Spot_firstdiff_lag2 = lagmatrix(ECM4.Spot_firstdiff,2);
1182 ECM4.Spot_firstdiff_lag3 = lagmatrix(ECM4.Spot_firstdiff,3);
1183 ECM4.Spot_firstdiff_lag4 = lagmatrix(ECM4.Spot_firstdiff,4);
1184 ECM4.Spot_firstdiff_lag5 = lagmatrix(ECM4.Spot_firstdiff,5);
1185 ECM4.Spot_firstdiff_lag6 = lagmatrix(ECM4.Spot_firstdiff,6);
1186 ECM4.Spot_firstdiff_lag7 = lagmatrix(ECM4.Spot_firstdiff,7);
1187
1188 ECM4 = fitlm(ECM4, ['Spot_firstdiff ~ LaggedResiduals +
    Fut16_firstdiff_lag1 + Fut16_firstdiff_lag2' ...
1189     '+ Fut16_firstdiff_lag3 + Fut16_firstdiff_lag4 + Fut16_firstdiff_lag5
        + Fut16_firstdiff_lag6' ...
1190     '+ Fut16_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'

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1191     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
1192     Spot_firstdiff_lag6' ...
1193     '+ Spot_firstdiff_lag7'])
1194 % Engle's ARCH Test – Spot and Fut16:
1195 ECM4.SqResiduals = (ECM4.Residuals.Raw).^2;
1196 ECM4.res1 = lagmatrix(ECM4.SqResiduals,1);
1197 ECM4.res2 = lagmatrix(ECM4.SqResiduals,2);
1198 ECM4.res3 = lagmatrix(ECM4.SqResiduals,3);
1199 ECM4.res4 = lagmatrix(ECM4.SqResiduals,4);
1200 ECM4.res5 = lagmatrix(ECM4.SqResiduals,5);
1201 ECM4.res6 = lagmatrix(ECM4.SqResiduals,6);
1202 ECM4.res7 = lagmatrix(ECM4.SqResiduals,7);
1203 ECM4.res8 = lagmatrix(ECM4.SqResiduals,8);
1204 ECM4.res9 = lagmatrix(ECM4.SqResiduals,9);
1205 ECM4.res10 = lagmatrix(ECM4.SqResiduals,10);
1206 ECM4.res11 = lagmatrix(ECM4.SqResiduals,11);
1207 ECM4.res12 = lagmatrix(ECM4.SqResiduals,12);
1208
1209 ECM4 = fillmissing(ECM4, 'constant', 0, 'DataVariables', ...
1210     {'res1', 'res2', 'res3', 'res4', 'res5', 'res6', 'res7',
1211     ...
1212     'res8', 'res9', 'res10', 'res11', 'res12'});
1213 % Running the auxiliary regression
1214 AuxReg4 = fitlm(ECM4, ['SqResiduals ~ res1 + res2 + res3 + res3 + res4 +
1215     res5' ...
1216     '+ res6 + res7 + res8 + res9 + res10 + res11 + res12'])
1217 % Testing for autocorrelation:
1218 T = 976;
1219 alpha = [0.1, 0.05, 0.01]
1220 TestStatARCH = (T)*AuxReg4.Rsquared.Ordinary
1221 pVal = 1 - cdf('Chisquare', TestStatARCH, 12)
1222 criticalARCH = chi2inv(1-alpha, 12);
1223 rejection = TestStatARCH > criticalARCH
1224
1225 % ECM-GARCH: Spot and Fut16:
1226 GARCH4 = garch('GARCHlags', 1, 'ARCHlags', 1)
1227 [estMdl, estParamCov, logL] = estimate(GARCH4, ECM4.Spot_firstdiff)
1228 condVar = infer(estMdl, ECM4.Spot_firstdiff);
1229 ECM4.condVol = sqrt(condVar);
1230
1231 ECM_GARCH4 = fitlm(ECM4, ['Spot_firstdiff ~ LaggedResiduals +
1232     Fut16_firstdiff_lag1 + Fut16_firstdiff_lag2' ...
1233     '+ Fut16_firstdiff_lag3 + Fut16_firstdiff_lag4 + Fut16_firstdiff_lag5
1234     + Fut16_firstdiff_lag6' ...
1235     '+ Fut16_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'
1236     ...
1237     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
1238     Spot_firstdiff_lag6' ...
1239     '+ Spot_firstdiff_lag7 + condVol'])
1240
1241 figure;
1242 plot(ECM4.Date, ECM4.Spot_firstdiff);
1243 hold on
1244 plot(ECM4.Date, ECM4.condVol)
1245 hold off
1246 legend('Log-differenced spot price', 'Inferred volatility')
1247 box('off')

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1244 xtickformat('yyyy')
1245
1246 % Finding residuals between Spot and lagged Fut15:
1247 reg5 = table();
1248 reg5.Date = data.Date;
1249 reg5.Spot = data.Spot;
1250 reg5.LagFut15 = lagmatrix(data.Fut15,1);
1251 reg5(1,:) = [];
1252 reg5(730:end,:) = [];
1253 model5 = fitlm(reg5, 'Spot ~ LagFut15')
1254 reg5.residuals = model5.Residuals.Raw;
1255 plot(reg5.Date, reg5.residuals)
1256
1257 % Defining ECM variables – Spot and Fut15:
1258 ECM5 = table();
1259 ECM5.Date = reg5.Date;
1260 ECM5.Spot_firstdiff = data.Spot_firstdiff(2:730);
1261 ECM5.LaggedResiduals = lagmatrix(reg5.residuals,1);
1262 %Lag variables – Fut:
1263 ECM5.Fut15_firstdiff_lag1 = reg5.LagFut15 – lagmatrix(reg5.LagFut15,1);
1264 ECM5.Fut15_firstdiff_lag2 = lagmatrix(ECM5.Fut15_firstdiff_lag1,1);
1265 ECM5.Fut15_firstdiff_lag3 = lagmatrix(ECM5.Fut15_firstdiff_lag1,2);
1266 ECM5.Fut15_firstdiff_lag4 = lagmatrix(ECM5.Fut15_firstdiff_lag1,3);
1267 ECM5.Fut15_firstdiff_lag5 = lagmatrix(ECM5.Fut15_firstdiff_lag1,4);
1268 ECM5.Fut15_firstdiff_lag6 = lagmatrix(ECM5.Fut15_firstdiff_lag1,5);
1269 ECM5.Fut15_firstdiff_lag7 = lagmatrix(ECM5.Fut15_firstdiff_lag1,6);
1270 ECM5.Fut15_firstdiff_lag8 = lagmatrix(ECM5.Fut15_firstdiff_lag1,7);
1271 ECM5.Fut15_firstdiff_lag9 = lagmatrix(ECM5.Fut15_firstdiff_lag1,8);
1272 ECM5.Fut15_firstdiff_lag10 = lagmatrix(ECM5.Fut15_firstdiff_lag1,9);
1273
1274 %Lag variables spot:
1275 ECM5.Spot_firstdiff_lag1 = lagmatrix(ECM5.Spot_firstdiff,1);
1276 ECM5.Spot_firstdiff_lag2 = lagmatrix(ECM5.Spot_firstdiff,2);
1277 ECM5.Spot_firstdiff_lag3 = lagmatrix(ECM5.Spot_firstdiff,3);
1278 ECM5.Spot_firstdiff_lag4 = lagmatrix(ECM5.Spot_firstdiff,4);
1279 ECM5.Spot_firstdiff_lag5 = lagmatrix(ECM5.Spot_firstdiff,5);
1280 ECM5.Spot_firstdiff_lag6 = lagmatrix(ECM5.Spot_firstdiff,6);
1281 ECM5.Spot_firstdiff_lag7 = lagmatrix(ECM5.Spot_firstdiff,7);
1282 ECM5.Spot_firstdiff_lag8 = lagmatrix(ECM5.Spot_firstdiff,8);
1283 ECM5.Spot_firstdiff_lag9 = lagmatrix(ECM5.Spot_firstdiff,9);
1284 ECM5.Spot_firstdiff_lag10 = lagmatrix(ECM5.Spot_firstdiff,10);
1285
1286
1287
1288 ECM5 = fitlm(ECM5, ['Spot_firstdiff ~ LaggedResiduals +
1289     Fut15_firstdiff_lag1 + Fut15_firstdiff_lag2' ...
1290     '+ Fut15_firstdiff_lag3 + Fut15_firstdiff_lag4 + Fut15_firstdiff_lag5
1291     + Fut15_firstdiff_lag6' ...
1292     '+ Fut15_firstdiff_lag7 + Fut15_firstdiff_lag8 + Fut15_firstdiff_lag9
1293     + Fut15_firstdiff_lag10' ...
1294     '+ Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
1295     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
1296     Spot_firstdiff_lag6' ...
1297     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
1298     Spot_firstdiff_lag10'])
1299
1300 % Engle's ARCH Test – Spot and Fut15:
1301 ECM5.SqResiduals = (ECM5.Residuals.Raw).^2;
1302 ECM5.res1 = lagmatrix(ECM5.SqResiduals,1);
1303 ECM5.res2 = lagmatrix(ECM5.SqResiduals,2);
1304 ECM5.res3 = lagmatrix(ECM5.SqResiduals,3);

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1300 ECM5.res4 = lagmatrix(ECM5.SqResiduals,4);
1301 ECM5.res5 = lagmatrix(ECM5.SqResiduals,5);
1302 ECM5.res6 = lagmatrix(ECM5.SqResiduals,6);
1303 ECM5.res7 = lagmatrix(ECM5.SqResiduals,7);
1304 ECM5.res8 = lagmatrix(ECM5.SqResiduals,8);
1305 ECM5.res9 = lagmatrix(ECM5.SqResiduals,9);
1306 ECM5.res10 = lagmatrix(ECM5.SqResiduals,10);
1307 ECM5.res11 = lagmatrix(ECM5.SqResiduals,11);
1308 ECM5.res12 = lagmatrix(ECM5.SqResiduals,12);
1309
1310 ECM5 = fillmissing(ECM5, 'constant', 0, 'DataVariables', ...
1311                   {'res1','res2','res3','res4','res5','res6','res7',
1312                    ...
1313                    'res8','res9','res10','res11','res12'});
1314
1314 % Running the auxiliary regression
1315 AuxReg5 = fitlm(ECM5, ['SqResiduals ~ res1 + res2 + res3 + res3 + res4 +
1316                       '+ res5' ...
1317                       '+ res6 + res7 + res8 + res9 + res10 + res11 + res12'])
1318
1318 % Testing for ARCH effects:
1319 T = 719;
1320 alpha = [0.1, 0.05, 0.01]
1321 TestStatARCH = (T)*AuxReg5.Rsquared.Ordinary
1322 pVal = 1 - cdf('Chisquare', TestStatARCH, 12)
1323 criticalARCH = chi2inv(1-alpha, 12);
1324 rejection = TestStatARCH > criticalARCH
1325
1326 % ECM-GARCH: Spot and Fut15:
1327 GARCH5 = garch('GARCHlags', 1, 'ARCHlags', 1)
1328 [estMdl, estParamCov, logL] = estimate(GARCH5, ECM5.Spot_firstdiff)
1329 condVar = infer(estMdl, ECM5.Spot_firstdiff);
1330 ECM5.condVol = sqrt(condVar);
1331
1332 ECM_GARCH5 = fitlm(ECM5, ['Spot_firstdiff ~ LaggedResiduals +
1333                           Fut15_firstdiff_lag1 + Fut15_firstdiff_lag2' ...
1334                           '+ Fut15_firstdiff_lag3 + Fut15_firstdiff_lag4 + Fut15_firstdiff_lag5
1335                           + Fut15_firstdiff_lag6' ...
1336                           '+ Fut15_firstdiff_lag7 + Fut15_firstdiff_lag8 + Fut15_firstdiff_lag9
1337                           + Fut15_firstdiff_lag10' ...
1338                           '+ Spot_firstdiff_lag1 + Spot_firstdiff_lag2 + Spot_firstdiff_lag3 +
1339                           Spot_firstdiff_lag4' ...
1340                           '+ Spot_firstdiff_lag5 + Spot_firstdiff_lag6 + Spot_firstdiff_lag7 +
1341                           Spot_firstdiff_lag8' ...
1342                           '+ Spot_firstdiff_lag9 + Spot_firstdiff_lag10 + condVol'])
1343
1343 figure;
1344 plot(ECM5.Date, ECM5.Spot_firstdiff);
1345 hold on
1346 plot(ECM5.Date, ECM5.condVol);
1347 hold off
1348 legend('Log-differenced spot price', 'Inferred volatility')
1349 box('off')
1350 xtickformat('yyyy')
1351
1352 % Finding residuals between Spot and lagged Fut14:
1353 reg6 = table();
1354 reg6.Date = data.Date;
1355 reg6.Spot = data.Spot;
1356 reg6.LagFut14 = lagmatrix(data.Fut14,1);
1357 reg6(1,:) = [];

```



```

1354 reg6(486:end,:) = [];
1355 model6 = fitlm(reg6, 'Spot ~ LagFut14')
1356 reg6.residuals = model6.Residuals.Raw;
1357 plot(reg6.Date, reg6.residuals)
1358
1359 % Defining ECM variables – Spot and Fut14:
1360 ECM6 = table();
1361 ECM6.Date = reg6.Date;
1362 ECM6.Spot_firstdiff = data.Spot_firstdiff(2:486);
1363 ECM6.LaggedResiduals = lagmatrix(reg6.residuals,1);
1364 %Lag variables – Fut:
1365 ECM6.Fut14_firstdiff_lag1 = reg6.LagFut14 – lagmatrix(reg6.LagFut14,1);
1366 ECM6.Fut14_firstdiff_lag2 = lagmatrix(ECM6.Fut14_firstdiff_lag1,1);
1367 ECM6.Fut14_firstdiff_lag3 = lagmatrix(ECM6.Fut14_firstdiff_lag1,2);
1368 ECM6.Fut14_firstdiff_lag4 = lagmatrix(ECM6.Fut14_firstdiff_lag1,3);
1369 ECM6.Fut14_firstdiff_lag5 = lagmatrix(ECM6.Fut14_firstdiff_lag1,4);
1370 ECM6.Fut14_firstdiff_lag6 = lagmatrix(ECM6.Fut14_firstdiff_lag1,5);
1371 ECM6.Fut14_firstdiff_lag7 = lagmatrix(ECM6.Fut14_firstdiff_lag1,6);
1372
1373 %Lag variables spot:
1374 ECM6.Spot_firstdiff_lag1 = lagmatrix(ECM6.Spot_firstdiff,1);
1375 ECM6.Spot_firstdiff_lag2 = lagmatrix(ECM6.Spot_firstdiff,2);
1376 ECM6.Spot_firstdiff_lag3 = lagmatrix(ECM6.Spot_firstdiff,3);
1377 ECM6.Spot_firstdiff_lag4 = lagmatrix(ECM6.Spot_firstdiff,4);
1378 ECM6.Spot_firstdiff_lag5 = lagmatrix(ECM6.Spot_firstdiff,5);
1379 ECM6.Spot_firstdiff_lag6 = lagmatrix(ECM6.Spot_firstdiff,6);
1380 ECM6.Spot_firstdiff_lag7 = lagmatrix(ECM6.Spot_firstdiff,7);
1381
1382 ECM6 = fitlm(ECM6, ['Spot_firstdiff ~ LaggedResiduals +
    Fut14_firstdiff_lag1 + Fut14_firstdiff_lag2' ...
1383     '+ Fut14_firstdiff_lag3 + Fut14_firstdiff_lag4 + Fut14_firstdiff_lag5
    + Fut14_firstdiff_lag6' ...
1384     '+ Fut14_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'
    ...
1385     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
1386     '+ Spot_firstdiff_lag7'])
1387
1388 % Engle's ARCH Test – Spot and Fut14:
1389 ECM6.SqResiduals = (ECM6.Residuals.Raw).^2;
1390 ECM6.res1 = lagmatrix(ECM6.SqResiduals,1);
1391 ECM6.res2 = lagmatrix(ECM6.SqResiduals,2);
1392 ECM6.res3 = lagmatrix(ECM6.SqResiduals,3);
1393 ECM6.res4 = lagmatrix(ECM6.SqResiduals,4);
1394 ECM6.res5 = lagmatrix(ECM6.SqResiduals,5);
1395 ECM6.res6 = lagmatrix(ECM6.SqResiduals,6);
1396 ECM6.res7 = lagmatrix(ECM6.SqResiduals,7);
1397 ECM6.res8 = lagmatrix(ECM6.SqResiduals,8);
1398 ECM6.res9 = lagmatrix(ECM6.SqResiduals,9);
1399 ECM6.res10 = lagmatrix(ECM6.SqResiduals,10);
1400 ECM6.res11 = lagmatrix(ECM6.SqResiduals,11);
1401 ECM6.res12 = lagmatrix(ECM6.SqResiduals,12);
1402
1403 ECM6 = fillmissing(ECM6, 'constant', 0, 'DataVariables', ...
1404     {'res1', 'res2', 'res3', 'res4', 'res5', 'res6', 'res7',
    ...
    'res8', 'res9', 'res10', 'res11', 'res12'});
1405
1406
1407 % Running the auxiliary regression
1408 AuxReg6 = fitlm(ECM6, ['SqResiduals ~ res1 + res2 + res3 + res3 + res4 +
    res5' ...

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1409     '+ res6 + res7 + res8 + res9 + res10 + res11 + res12']])
1410
1411 % Testing for ARCH effects:
1412 T = 478;
1413 alpha = [0.1, 0.05, 0.01]
1414 TestStatARCH = (T)*AuxReg6.Rsquared.Ordinary
1415 pVal = 1 - cdf('Chisquare', TestStatARCH, 12)
1416 criticalARCH = chi2inv(1-alpha, 12);
1417 rejection = TestStatARCH > criticalARCH
1418
1419 % ECM-GARCH: Spot and Fut14:
1420 GARCH6 = garch('GARCHlags', 1, 'ARCHlags', 1)
1421 [estMdl, estParamCov, logL] = estimate(GARCH6, ECM6.Spot_firstdiff)
1422 condVar = infer(estMdl, ECM6.Spot_firstdiff);
1423 ECM6.condVol = sqrt(condVar);
1424
1425 ECM_GARCH6 = fitlm(ECM6, ['Spot_firstdiff ~ LaggedResiduals +
    Fut14_firstdiff_lag1 + Fut14_firstdiff_lag2' ...
1426     '+ Fut14_firstdiff_lag3 + Fut14_firstdiff_lag4 + Fut14_firstdiff_lag5
        + Fut14_firstdiff_lag6' ...
1427     '+ Fut14_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'
        ...
1428     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
        Spot_firstdiff_lag6' ...
1429     '+ Spot_firstdiff_lag7 + condVol'])
1430
1431 figure;
1432 plot(ECM6.Date, ECM6.Spot_firstdiff);
1433 hold on
1434 plot(ECM6.Date, ECM6.condVol)
1435 hold off
1436 legend('Log-differenced spot price', 'Inferred volatility')
1437 box('off');
1438 xtickformat('yyyy')
1439
1440 %% Part 5 – Predictions by ECM and ECM-GARCH (re-estimation of all models
    ):
1441 clear;
1442 clc;
1443
1444 % Importing data and creating variables for sample matching after
    estimation:
1445 data = readtable('Spot+DecFutures.xlsx');
1446 data=data(~any(ismissing(data.Spot),2),:);
1447 data(584:585,:) = [];
1448 data = table2timetable(data);
1449 data.Spot = log(data.Spot);
1450 data.Fut19 = log(data.Fut19);
1451 data.Fut18 = log(data.Fut18);
1452 data.Fut17 = log(data.Fut17);
1453 data.Fut16 = log(data.Fut16);
1454 data.Fut15 = log(data.Fut15);
1455 data.Fut14 = log(data.Fut14);
1456
1457 % Creating first differences and lags:
1458 data.Spot_firstdiff = data.Spot - lagmatrix(data.Spot,1);
1459 data.Spot_firstdiff_lag1 = lagmatrix(data.Spot_firstdiff,1);
1460 data.Spot_firstdiff_lag2 = lagmatrix(data.Spot_firstdiff,2);
1461 data.Spot_firstdiff_lag3 = lagmatrix(data.Spot_firstdiff,3);
1462 data.Spot_firstdiff_lag4 = lagmatrix(data.Spot_firstdiff,4);
1463 data.Spot_firstdiff_lag5 = lagmatrix(data.Spot_firstdiff,5);

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1464 data.Spot_firstdiff_lag6 = lagmatrix(data.Spot_firstdiff,6);
1465 data.Spot_firstdiff_lag7 = lagmatrix(data.Spot_firstdiff,7);
1466 data.Spot_firstdiff_lag8 = lagmatrix(data.Spot_firstdiff,8);
1467 data.Spot_firstdiff_lag9 = lagmatrix(data.Spot_firstdiff,9);
1468 data.Spot_firstdiff_lag10 = lagmatrix(data.Spot_firstdiff,10);
1469 data.Spot_firstdiff_lag11 = lagmatrix(data.Spot_firstdiff,11);
1470 data.Spot_firstdiff_lag12 = lagmatrix(data.Spot_firstdiff,12);
1471
1472 data.Fut19_firstdiff = data.Fut19 - lagmatrix(data.Fut19,1);
1473 data.Fut19_firstdiff_lag1 = lagmatrix(data.Fut19_firstdiff,1);
1474 data.Fut19_firstdiff_lag2 = lagmatrix(data.Fut19_firstdiff,2);
1475 data.Fut19_firstdiff_lag3 = lagmatrix(data.Fut19_firstdiff,3);
1476 data.Fut19_firstdiff_lag4 = lagmatrix(data.Fut19_firstdiff,4);
1477 data.Fut19_firstdiff_lag5 = lagmatrix(data.Fut19_firstdiff,5);
1478 data.Fut19_firstdiff_lag6 = lagmatrix(data.Fut19_firstdiff,6);
1479 data.Fut19_firstdiff_lag7 = lagmatrix(data.Fut19_firstdiff,7);
1480 data.Fut19_firstdiff_lag8 = lagmatrix(data.Fut19_firstdiff,8);
1481 data.Fut19_firstdiff_lag9 = lagmatrix(data.Fut19_firstdiff,9);
1482 data.Fut19_firstdiff_lag10 = lagmatrix(data.Fut19_firstdiff,10);
1483 data.Fut19_firstdiff_lag11 = lagmatrix(data.Fut19_firstdiff,11);
1484 data.Fut19_firstdiff_lag12 = lagmatrix(data.Fut19_firstdiff,12);
1485
1486 data.Fut18_firstdiff = data.Fut18 - lagmatrix(data.Fut18,1);
1487 data.Fut18_firstdiff_lag1 = lagmatrix(data.Fut18_firstdiff,1);
1488 data.Fut18_firstdiff_lag2 = lagmatrix(data.Fut18_firstdiff,2);
1489 data.Fut18_firstdiff_lag3 = lagmatrix(data.Fut18_firstdiff,3);
1490 data.Fut18_firstdiff_lag4 = lagmatrix(data.Fut18_firstdiff,4);
1491 data.Fut18_firstdiff_lag5 = lagmatrix(data.Fut18_firstdiff,5);
1492 data.Fut18_firstdiff_lag6 = lagmatrix(data.Fut18_firstdiff,6);
1493 data.Fut18_firstdiff_lag7 = lagmatrix(data.Fut18_firstdiff,7);
1494 data.Fut18_firstdiff_lag8 = lagmatrix(data.Fut18_firstdiff,8);
1495
1496 data.Fut17_firstdiff = data.Fut17 - lagmatrix(data.Fut17,1);
1497 data.Fut17_firstdiff_lag1 = lagmatrix(data.Fut17_firstdiff,1);
1498 data.Fut17_firstdiff_lag2 = lagmatrix(data.Fut17_firstdiff,2);
1499 data.Fut17_firstdiff_lag3 = lagmatrix(data.Fut17_firstdiff,3);
1500 data.Fut17_firstdiff_lag4 = lagmatrix(data.Fut17_firstdiff,4);
1501 data.Fut17_firstdiff_lag5 = lagmatrix(data.Fut17_firstdiff,5);
1502 data.Fut17_firstdiff_lag6 = lagmatrix(data.Fut17_firstdiff,6);
1503 data.Fut17_firstdiff_lag7 = lagmatrix(data.Fut17_firstdiff,7);
1504 data.Fut17_firstdiff_lag8 = lagmatrix(data.Fut17_firstdiff,8);
1505 data.Fut17_firstdiff_lag9 = lagmatrix(data.Fut17_firstdiff,9);
1506 data.Fut17_firstdiff_lag10 = lagmatrix(data.Fut17_firstdiff,10);
1507 data.Fut17_firstdiff_lag11 = lagmatrix(data.Fut17_firstdiff,11);
1508 data.Fut17_firstdiff_lag12 = lagmatrix(data.Fut17_firstdiff,12);
1509
1510 data.Fut16_firstdiff = data.Fut16 - lagmatrix(data.Fut16,1);
1511 data.Fut16_firstdiff_lag1 = lagmatrix(data.Fut16_firstdiff,1);
1512 data.Fut16_firstdiff_lag2 = lagmatrix(data.Fut16_firstdiff,2);
1513 data.Fut16_firstdiff_lag3 = lagmatrix(data.Fut16_firstdiff,3);
1514 data.Fut16_firstdiff_lag4 = lagmatrix(data.Fut16_firstdiff,4);
1515 data.Fut16_firstdiff_lag5 = lagmatrix(data.Fut16_firstdiff,5);
1516 data.Fut16_firstdiff_lag6 = lagmatrix(data.Fut16_firstdiff,6);
1517 data.Fut16_firstdiff_lag7 = lagmatrix(data.Fut16_firstdiff,7);
1518
1519 data.Fut15_firstdiff = data.Fut15 - lagmatrix(data.Fut15,1);
1520 data.Fut15_firstdiff_lag1 = lagmatrix(data.Fut15_firstdiff,1);
1521 data.Fut15_firstdiff_lag2 = lagmatrix(data.Fut15_firstdiff,2);
1522 data.Fut15_firstdiff_lag3 = lagmatrix(data.Fut15_firstdiff,3);
1523 data.Fut15_firstdiff_lag4 = lagmatrix(data.Fut15_firstdiff,4);
1524 data.Fut15_firstdiff_lag5 = lagmatrix(data.Fut15_firstdiff,5);

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1525 data.Fut15_firstdiff_lag6 = lagmatrix(data.Fut15_firstdiff,6);
1526 data.Fut15_firstdiff_lag7 = lagmatrix(data.Fut15_firstdiff,7);
1527 data.Fut15_firstdiff_lag8 = lagmatrix(data.Fut15_firstdiff,8);
1528 data.Fut15_firstdiff_lag9 = lagmatrix(data.Fut15_firstdiff,9);
1529 data.Fut15_firstdiff_lag10 = lagmatrix(data.Fut15_firstdiff,10);
1530
1531 data.Fut14_firstdiff = data.Fut14 - lagmatrix(data.Fut14,1);
1532 data.Fut14_firstdiff_lag1 = lagmatrix(data.Fut14_firstdiff,1);
1533 data.Fut14_firstdiff_lag2 = lagmatrix(data.Fut14_firstdiff,2);
1534 data.Fut14_firstdiff_lag3 = lagmatrix(data.Fut14_firstdiff,3);
1535 data.Fut14_firstdiff_lag4 = lagmatrix(data.Fut14_firstdiff,4);
1536 data.Fut14_firstdiff_lag5 = lagmatrix(data.Fut14_firstdiff,5);
1537 data.Fut14_firstdiff_lag6 = lagmatrix(data.Fut14_firstdiff,6);
1538 data.Fut14_firstdiff_lag7 = lagmatrix(data.Fut14_firstdiff,7);
1539
1540 % Finding residuals between Spot and lagged Fut19:
1541 reg1 = table();
1542 reg1.Date = data.Date(1:1460);
1543 reg1.Spot = data.Spot(1:1460);
1544 reg1.LagFut19 = lagmatrix(data.Fut19(1:1460),1);
1545 reg1(1,:) = [];
1546 modell = fitlm(reg1, 'Spot ~ LagFut19')
1547 reg1.residuals1 = modell.Residuals.Raw;
1548
1549 % Defining ECM variables - Spot and Fut19:
1550 ECM1 = table();
1551 ECM1.Date = reg1.Date;
1552 ECM1.Spot_firstdiff = data.Spot_firstdiff(2:1460);
1553 ECM1.LaggedResiduals = lagmatrix(reg1.residuals1,1);
1554 %Lag variables - Fut:
1555 ECM1.Fut19_firstdiff_lag1 = reg1.LagFut19 - lagmatrix(reg1.LagFut19,1);
1556 ECM1.Fut19_firstdiff_lag2 = lagmatrix(ECM1.Fut19_firstdiff_lag1,1);
1557 ECM1.Fut19_firstdiff_lag3 = lagmatrix(ECM1.Fut19_firstdiff_lag1,2);
1558 ECM1.Fut19_firstdiff_lag4 = lagmatrix(ECM1.Fut19_firstdiff_lag1,3);
1559 ECM1.Fut19_firstdiff_lag5 = lagmatrix(ECM1.Fut19_firstdiff_lag1,4);
1560 ECM1.Fut19_firstdiff_lag6 = lagmatrix(ECM1.Fut19_firstdiff_lag1,5);
1561 ECM1.Fut19_firstdiff_lag7 = lagmatrix(ECM1.Fut19_firstdiff_lag1,6);
1562 ECM1.Fut19_firstdiff_lag8 = lagmatrix(ECM1.Fut19_firstdiff_lag1,7);
1563 ECM1.Fut19_firstdiff_lag9 = lagmatrix(ECM1.Fut19_firstdiff_lag1,8);
1564 ECM1.Fut19_firstdiff_lag10 = lagmatrix(ECM1.Fut19_firstdiff_lag1,9);
1565 ECM1.Fut19_firstdiff_lag11 = lagmatrix(ECM1.Fut19_firstdiff_lag1,10);
1566 ECM1.Fut19_firstdiff_lag12 = lagmatrix(ECM1.Fut19_firstdiff_lag1,11);
1567 %Lag variables spot:
1568 ECM1.Spot_firstdiff_lag1 = lagmatrix(ECM1.Spot_firstdiff,1);
1569 ECM1.Spot_firstdiff_lag2 = lagmatrix(ECM1.Spot_firstdiff,2);
1570 ECM1.Spot_firstdiff_lag3 = lagmatrix(ECM1.Spot_firstdiff,3);
1571 ECM1.Spot_firstdiff_lag4 = lagmatrix(ECM1.Spot_firstdiff,4);
1572 ECM1.Spot_firstdiff_lag5 = lagmatrix(ECM1.Spot_firstdiff,5);
1573 ECM1.Spot_firstdiff_lag6 = lagmatrix(ECM1.Spot_firstdiff,6);
1574 ECM1.Spot_firstdiff_lag7 = lagmatrix(ECM1.Spot_firstdiff,7);
1575 ECM1.Spot_firstdiff_lag8 = lagmatrix(ECM1.Spot_firstdiff,8);
1576 ECM1.Spot_firstdiff_lag9 = lagmatrix(ECM1.Spot_firstdiff,9);
1577 ECM1.Spot_firstdiff_lag10 = lagmatrix(ECM1.Spot_firstdiff,10);
1578 ECM1.Spot_firstdiff_lag11 = lagmatrix(ECM1.Spot_firstdiff,11);
1579 ECM1.Spot_firstdiff_lag12 = lagmatrix(ECM1.Spot_firstdiff,12);
1580
1581 ECM1 = fitlm(ECM1, ['Spot_firstdiff ~ LaggedResiduals +
1582     Fut19_firstdiff_lag1 + Fut19_firstdiff_lag2' ...
1583     '+ Fut19_firstdiff_lag3 + Fut19_firstdiff_lag4 + Fut19_firstdiff_lag5
1584     + Fut19_firstdiff_lag6' ...
1585     '+ Fut19_firstdiff_lag7 + Fut19_firstdiff_lag8 + Fut19_firstdiff_lag9

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1584     + Fut19_firstdiff_lag10' ...
1585 '+ Fut19_firstdiff_lag11 + Fut19_firstdiff_lag12 +
    Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
1586 '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
1587 '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
    Spot_firstdiff_lag10' ...
1588 '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12']])
1589 residuals = table();
1590 residuals.Date = data.Date;
1591 residuals.LaggedResiduals = zeros(1709,1);
1592
1593 for i = 1460:1709
1594     reg = table();
1595     reg.Date = data.Date(1:i);
1596     reg.Spot = data.Spot(1:i);
1597     reg.LagFut19 = lagmatrix(data.Fut19(1:i),1);
1598     reg(1,:) = [];
1599     model = fitlm(reg, 'Spot ~ LagFut19');
1600     reg.residuals = model.Residuals.Raw;
1601     residuals.LaggedResiduals(i+1) = reg.residuals(end);
1602 end
1603
1604 residuals(1:1460,:) = [];
1605 residuals(250,:) = [];
1606
1607 Predicted_SpotFD_ECM1 = [ECM1.Coefficients.Estimate(1) + ECM1.
    Coefficients.Estimate(3)*data.Fut19_firstdiff_lag1(1461:end) ...
1608 + ECM1.Coefficients.Estimate(4)*data.Fut19_firstdiff_lag2(1461:end)
    + ECM1.Coefficients.Estimate(5)*data.Fut19_firstdiff_lag3(1461:
    end) ...
1609 + ECM1.Coefficients.Estimate(6)*data.Fut19_firstdiff_lag4(1461:end)
    + ECM1.Coefficients.Estimate(7)*data.Fut19_firstdiff_lag5(1461:
    end) ...
1610 + ECM1.Coefficients.Estimate(8)*data.Fut19_firstdiff_lag6(1461:end)
    + ECM1.Coefficients.Estimate(9)*data.Fut19_firstdiff_lag7(1461:
    end) ...
1611 + ECM1.Coefficients.Estimate(10)*data.Fut19_firstdiff_lag8(1461:end)
    + ECM1.Coefficients.Estimate(11)*data.Fut19_firstdiff_lag9(1461:
    end) ...
1612 + ECM1.Coefficients.Estimate(12)*data.Fut19_firstdiff_lag10(1461:end)
    + ECM1.Coefficients.Estimate(13)*data.Fut19_firstdiff_lag11
    (1461:end) ...
1613 + ECM1.Coefficients.Estimate(14)*data.Fut19_firstdiff_lag12(1461:end)
    + ECM1.Coefficients.Estimate(15)*data.Spot_firstdiff_lag1(1461:
    end) ...
1614 + ECM1.Coefficients.Estimate(16)*data.Spot_firstdiff_lag2(1461:end)
    + ECM1.Coefficients.Estimate(17)*data.Spot_firstdiff_lag3(1461:
    end) ...
1615 + ECM1.Coefficients.Estimate(18)*data.Spot_firstdiff_lag4(1461:end)
    + ECM1.Coefficients.Estimate(19)*data.Spot_firstdiff_lag5(1461:
    end) ...
1616 + ECM1.Coefficients.Estimate(20)*data.Spot_firstdiff_lag6(1461:end)
    + ECM1.Coefficients.Estimate(21)*data.Spot_firstdiff_lag7(1461:
    end) ...
1617 + ECM1.Coefficients.Estimate(22)*data.Spot_firstdiff_lag8(1461:end)
    + ECM1.Coefficients.Estimate(23)*data.Spot_firstdiff_lag9(1461:
    end) ...
1618 + ECM1.Coefficients.Estimate(24)*data.Spot_firstdiff_lag10(1461:end)
    + ECM1.Coefficients.Estimate(25)*data.Spot_firstdiff_lag11(1461:

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    end) ...
1619     + ECM1.Coefficients.Estimate(26)*data.Spot_firstdiff_lag12(1461:end)
        + ECM1.Coefficients.Estimate(2)*residuals.LaggedResiduals];
1620
1621 Predictions_ECM1 = table();
1622 Predictions_ECM1.Date = data.Date(1460:end);
1623 Predictions_ECM1.Spot = data.Spot(1460:end);
1624 Predictions_ECM1.PredictedSpotFD = zeros(250,1);
1625 Predictions_ECM1.PredictedSpotFD(2:end) = Predicted_SpotFD_ECM1;
1626 Predictions_ECM1.PredictedSpot = lagmatrix(Predictions_ECM1.Spot, 1) +
    Predictions_ECM1.PredictedSpotFD;
1627 Predictions_ECM1(1,:) = [];
1628 Predictions_ECM1.Spot = exp(Predictions_ECM1.Spot);
1629 Predictions_ECM1.PredictedSpot = exp(Predictions_ECM1.PredictedSpot);
1630 Predictions_ECM1(241:end,:) = [];
1631
1632 MSE_ECM1 = (sum(Predictions_ECM1.PredictedSpot - Predictions_ECM1.Spot)
    ^2)/(240);
1633 RMSE_ECM1 = sqrt(MSE_ECM1)
1634
1635 ChangePred_ECM1 = Predictions_ECM1.PredictedSpot - lagmatrix(
    Predictions_ECM1.PredictedSpot, 1);
1636 ChangeSpot_ECM1 = Predictions_ECM1.Spot - lagmatrix(Predictions_ECM1.Spot
    , 1);
1637
1638 SignPred_ECM1 = table();
1639 for i = 1:height(Predictions_ECM1)
1640     if ChangePred_ECM1(i) >= 0 & ChangeSpot_ECM1(i) >= 0
1641         SignPred_ECM1.True(i) = 1;
1642     else
1643         SignPred_ECM1.True(i) = 0;
1644     end
1645 end
1646
1647 for i = 1:height(Predictions_ECM1)
1648     if ChangePred_ECM1(i) <= 0 & ChangeSpot_ECM1(i) <= 0
1649         SignPred_ECM1.True1(i) = 1;
1650     else
1651         SignPred_ECM1.True1(i) = 0;
1652     end
1653 end
1654 PercentCorrect_ECM1 = (sum(SignPred_ECM1.True) + sum(SignPred_ECM1.True1)
    ) / (height(Predictions_ECM1));
1655
1656 % ECM-GARCH: Spot and Fut19:
1657 GARCH1 = garch('GARCHlags', 1, 'ARCHlags', 1)
1658 [estMdl, estParamCov, logL] = estimate(GARCH1, ECM1.Spot_firstdiff)
1659 condVar = infer(estMdl, ECM1.Spot_firstdiff);
1660 ECM1.condVol = sqrt(condVar);
1661
1662 ECM_GARCH1 = fitlm(ECM1, ['Spot_firstdiff ~ LaggedResiduals +
    Fut19_firstdiff_lag1 + Fut19_firstdiff_lag2' ...
1663     '+ Fut19_firstdiff_lag3 + Fut19_firstdiff_lag4 + Fut19_firstdiff_lag5
        + Fut19_firstdiff_lag6' ...
1664     '+ Fut19_firstdiff_lag7 + Fut19_firstdiff_lag8 + Fut19_firstdiff_lag9
        + Fut19_firstdiff_lag10' ...
1665     '+ Fut19_firstdiff_lag11 + Fut19_firstdiff_lag12 +
        Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
1666     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
        Spot_firstdiff_lag6' ...
1667     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +

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    Spot_firstdiff_lag10' ...
1668 '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12 + condVol']])
1669
1670 Pred19 = forecast(estMdl, height(residuals), 'Y0', ECM1.Spot_firstdiff);
1671 Pred19_Vol = sqrt(Pred19);
1672
1673
1674 Predicted_SpotFD_GARCH1 = [ECM.GARCH1.Coefficients.Estimate(1) +
    ECM.GARCH1.Coefficients.Estimate(3)*data.Fut19_firstdiff_lag1(1461:
    end) ...
1675 + ECM.GARCH1.Coefficients.Estimate(4)*data.Fut19_firstdiff_lag2
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(5)*data.
    Fut19_firstdiff_lag3(1461:end) ...
1676 + ECM.GARCH1.Coefficients.Estimate(6)*data.Fut19_firstdiff_lag4
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(7)*data.
    Fut19_firstdiff_lag5(1461:end) ...
1677 + ECM.GARCH1.Coefficients.Estimate(8)*data.Fut19_firstdiff_lag6
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(9)*data.
    Fut19_firstdiff_lag7(1461:end) ...
1678 + ECM.GARCH1.Coefficients.Estimate(10)*data.Fut19_firstdiff_lag8
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(11)*data.
    Fut19_firstdiff_lag9(1461:end) ...
1679 + ECM.GARCH1.Coefficients.Estimate(12)*data.Fut19_firstdiff_lag10
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(13)*data.
    Fut19_firstdiff_lag11(1461:end) ...
1680 + ECM.GARCH1.Coefficients.Estimate(14)*data.Fut19_firstdiff_lag12
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(15)*data.
    Spot_firstdiff_lag1(1461:end) ...
1681 + ECM.GARCH1.Coefficients.Estimate(16)*data.Spot_firstdiff_lag2
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(17)*data.
    Spot_firstdiff_lag3(1461:end) ...
1682 + ECM.GARCH1.Coefficients.Estimate(18)*data.Spot_firstdiff_lag4
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(19)*data.
    Spot_firstdiff_lag5(1461:end) ...
1683 + ECM.GARCH1.Coefficients.Estimate(20)*data.Spot_firstdiff_lag6
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(21)*data.
    Spot_firstdiff_lag7(1461:end) ...
1684 + ECM.GARCH1.Coefficients.Estimate(22)*data.Spot_firstdiff_lag8
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(23)*data.
    Spot_firstdiff_lag9(1461:end) ...
1685 + ECM.GARCH1.Coefficients.Estimate(24)*data.Spot_firstdiff_lag10
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(25)*data.
    Spot_firstdiff_lag11(1461:end) ...
1686 + ECM.GARCH1.Coefficients.Estimate(26)*data.Spot_firstdiff_lag12
    (1461:end) + ECM.GARCH1.Coefficients.Estimate(2)*residuals.
    LaggedResiduals ...
1687 + ECM.GARCH1.Coefficients.Estimate(27)*Pred19_Vol];
1688
1689 Predictions_GARCH1 = table();
1690 Predictions_GARCH1.Date = data.Date(1460:end);
1691 Predictions_GARCH1.Spot = data.Spot(1460:end);
1692 Predictions_GARCH1.PredictedSpotFD = zeros(250,1);
1693 Predictions_GARCH1.PredictedSpotFD(2:end) = Predicted_SpotFD_GARCH1;
1694 Predictions_GARCH1.PredictedSpot = lagmatrix(Predictions_GARCH1.Spot, 1)
    + Predictions_GARCH1.PredictedSpotFD;
1695 Predictions_GARCH1(1,:) = [];
1696 Predictions_GARCH1.Spot = exp(Predictions_GARCH1.Spot);
1697 Predictions_GARCH1.PredictedSpot = exp(Predictions_GARCH1.PredictedSpot);
1698 Predictions_GARCH1(241:end,:) = [];
1699
1700 MSE.GARCH1 = (sum(Predictions_GARCH1.PredictedSpot - Predictions_GARCH1.

```

```

    Spot)^2)/(240);
1701 RMSE_GARCH1 = sqrt(MSE_GARCH1)
1702
1703 ChangePred_GARCH1 = Predictions_GARCH1.PredictedSpot - lagmatrix(
    Predictions_GARCH1.PredictedSpot, 1);
1704 ChangeSpot_GARCH1 = Predictions_GARCH1.Spot - lagmatrix(
    Predictions_GARCH1.Spot, 1);
1705
1706 SignPred_GARCH1 = table();
1707 for i = 1:height(Predictions_GARCH1)
1708     if ChangePred_GARCH1(i) >= 0 & ChangeSpot_GARCH1(i) >= 0
1709         SignPred_GARCH1.True(i) = 1;
1710     else
1711         SignPred_GARCH1.True(i) = 0;
1712     end
1713 end
1714
1715 for i = 1:height(Predictions_GARCH1)
1716     if ChangePred_GARCH1(i) <= 0 & ChangeSpot_GARCH1(i) <= 0
1717         SignPred_GARCH1.True1(i) = 1;
1718     else
1719         SignPred_GARCH1.True1(i) = 0;
1720     end
1721 end
1722 PercentCorrect_GARCH1 = (sum(SignPred_GARCH1.True) + sum(SignPred_GARCH1.
    True1)) / (height(Predictions_GARCH1));
1723
1724
1725 % Finding residuals between Spot and lagged Fut18:
1726 reg2 = table();
1727 reg2.Date = data.Date(1:1214);
1728 reg2.Spot = data.Spot(1:1214);
1729 reg2.LagFut18 = lagmatrix(data.Fut18(1:1214),1);
1730 reg2(1,:) = [];
1731 model2 = fitlm(reg2, 'Spot ~ LagFut18')
1732 reg2.residuals2 = model2.Residuals.Raw;
1733
1734 % Defining ECM variables - Spot and Fut18:
1735 ECM2 = table();
1736 ECM2.Date = reg2.Date;
1737 ECM2.Spot_firstdiff = data.Spot_firstdiff(2:1214);
1738 ECM2.LaggedResiduals = lagmatrix(reg2.residuals2,1);
1739 % Lag variables - Fut:
1740 ECM2.Fut18_firstdiff_lag1 = reg2.LagFut18 - lagmatrix(reg2.LagFut18,1);
1741 ECM2.Fut18_firstdiff_lag2 = lagmatrix(ECM2.Fut18_firstdiff_lag1,1);
1742 ECM2.Fut18_firstdiff_lag3 = lagmatrix(ECM2.Fut18_firstdiff_lag1,2);
1743 ECM2.Fut18_firstdiff_lag4 = lagmatrix(ECM2.Fut18_firstdiff_lag1,3);
1744 ECM2.Fut18_firstdiff_lag5 = lagmatrix(ECM2.Fut18_firstdiff_lag1,4);
1745 ECM2.Fut18_firstdiff_lag6 = lagmatrix(ECM2.Fut18_firstdiff_lag1,5);
1746 ECM2.Fut18_firstdiff_lag7 = lagmatrix(ECM2.Fut18_firstdiff_lag1,6);
1747 ECM2.Fut18_firstdiff_lag8 = lagmatrix(ECM2.Fut18_firstdiff_lag1,7);
1748 % Lag variables spot:
1749 ECM2.Spot_firstdiff_lag1 = lagmatrix(ECM2.Spot_firstdiff,1);
1750 ECM2.Spot_firstdiff_lag2 = lagmatrix(ECM2.Spot_firstdiff,2);
1751 ECM2.Spot_firstdiff_lag3 = lagmatrix(ECM2.Spot_firstdiff,3);
1752 ECM2.Spot_firstdiff_lag4 = lagmatrix(ECM2.Spot_firstdiff,4);
1753 ECM2.Spot_firstdiff_lag5 = lagmatrix(ECM2.Spot_firstdiff,5);
1754 ECM2.Spot_firstdiff_lag6 = lagmatrix(ECM2.Spot_firstdiff,6);
1755 ECM2.Spot_firstdiff_lag7 = lagmatrix(ECM2.Spot_firstdiff,7);
1756 ECM2.Spot_firstdiff_lag8 = lagmatrix(ECM2.Spot_firstdiff,8);
1757

```



```

1758 ECM2 = fitlm(ECM2, ['Spot_firstdiff ~ LaggedResiduals +
    Fut18_firstdiff_lag1 + Fut18_firstdiff_lag2' ...
1759     '+ Fut18_firstdiff_lag3 + Fut18_firstdiff_lag4 + Fut18_firstdiff_lag5
    + Fut18_firstdiff_lag6' ...
1760     '+ Fut18_firstdiff_lag7 + Fut18_firstdiff_lag8 + Spot_firstdiff_lag1
    + Spot_firstdiff_lag2' ...
1761     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
1762     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8'])
1763
1764 residuals_2 = table();
1765 residuals_2.Date = data.Date;
1766 residuals_2.LaggedResiduals = zeros(1709,1);
1767
1768 for i = 1214:1460
1769     reg = table();
1770     reg.Date = data.Date(1:i);
1771     reg.Spot = data.Spot(1:i);
1772     reg.LagFut18 = lagmatrix(data.Fut18(1:i),1);
1773     reg(1,:) = [];
1774     model = fitlm(reg, 'Spot ~ LagFut18');
1775     reg.residuals = model.Residuals.Raw;
1776     residuals_2.LaggedResiduals(i+1) = reg.residuals(end);
1777 end
1778
1779 residuals_2(1:1214,:) = [];
1780 residuals_2(247:end,:) = [];
1781
1782
1783 Predicted_SpotFD_ECM2 = [ECM2.Coefficients.Estimate(1) + ECM2.
    Coefficients.Estimate(3)*data.Fut18_firstdiff_lag1(1215:1460) ...
1784     + ECM2.Coefficients.Estimate(4)*data.Fut18_firstdiff_lag2(1215:1460)
    + ECM2.Coefficients.Estimate(5)*data.Fut18_firstdiff_lag3
    (1215:1460) ...
1785     + ECM2.Coefficients.Estimate(6)*data.Fut18_firstdiff_lag4(1215:1460)
    + ECM2.Coefficients.Estimate(7)*data.Fut18_firstdiff_lag5
    (1215:1460) ...
1786     + ECM2.Coefficients.Estimate(8)*data.Fut18_firstdiff_lag6(1215:1460)
    + ECM2.Coefficients.Estimate(9)*data.Fut18_firstdiff_lag7
    (1215:1460) ...
1787     + ECM2.Coefficients.Estimate(10)*data.Fut18_firstdiff_lag8
    (1215:1460) + ECM2.Coefficients.Estimate(11)*data.
    Spot_firstdiff_lag1(1215:1460) ...
1788     + ECM2.Coefficients.Estimate(12)*data.Spot_firstdiff_lag2(1215:1460)
    + ECM2.Coefficients.Estimate(13)*data.Spot_firstdiff_lag3
    (1215:1460) ...
1789     + ECM2.Coefficients.Estimate(14)*data.Spot_firstdiff_lag4(1215:1460)
    + ECM2.Coefficients.Estimate(15)*data.Spot_firstdiff_lag5
    (1215:1460) ...
1790     + ECM2.Coefficients.Estimate(16)*data.Spot_firstdiff_lag6(1215:1460)
    + ECM2.Coefficients.Estimate(17)*data.Spot_firstdiff_lag7
    (1215:1460) ...
1791     + ECM2.Coefficients.Estimate(18)*data.Spot_firstdiff_lag8(1215:1460)
    + ECM2.Coefficients.Estimate(2)*residuals_2.LaggedResiduals];
1792
1793 Predictions_ECM2 = table();
1794 Predictions_ECM2.Date = data.Date(1214:1460);
1795 Predictions_ECM2.Spot = data.Spot(1214:1460);
1796 Predictions_ECM2.PredictedSpotFD = zeros(247,1);
1797 Predictions_ECM2.PredictedSpotFD(2:end) = Predicted_SpotFD_ECM2;
1798 Predictions_ECM2.PredictedSpot = lagmatrix(Predictions_ECM2.Spot, 1) +

```

```

    Predictions_ECM2.PredictedSpotFD;
1799 Predictions_ECM2(1,:) = [];
1800 Predictions_ECM2.Spot = exp(Predictions_ECM2.Spot);
1801 Predictions_ECM2.PredictedSpot = exp(Predictions_ECM2.PredictedSpot);
1802 Predictions_ECM2(242:end,:) = [];
1803
1804 MSE_ECM2 = (sum(Predictions_ECM2.PredictedSpot - Predictions_ECM2.Spot)
    ^2)/(239);
1805 RMSE_ECM2 = sqrt(MSE_ECM2)
1806
1807 ChangePred_ECM2 = Predictions_ECM2.PredictedSpot - lagmatrix(
    Predictions_ECM2.PredictedSpot, 1);
1808 ChangeSpot_ECM2 = Predictions_ECM2.Spot - lagmatrix(Predictions_ECM2.Spot
    , 1);
1809
1810 SignPred_ECM2 = table();
1811 for i = 1:height(Predictions_ECM2)
1812     if ChangePred_ECM2(i) >= 0 & ChangeSpot_ECM2(i) >= 0
1813         SignPred_ECM2.True(i) = 1;
1814     else
1815         SignPred_ECM2.True(i) = 0;
1816     end
1817 end
1818
1819 for i = 1:height(Predictions_ECM2)
1820     if ChangePred_ECM2(i) <= 0 & ChangeSpot_ECM2(i) <= 0
1821         SignPred_ECM2.True1(i) = 1;
1822     else
1823         SignPred_ECM2.True1(i) = 0;
1824     end
1825 end
1826
1827 PercentCorrect_ECM2 = (sum(SignPred_ECM2.True) + sum(SignPred_ECM2.True1)
    ) / (height(Predictions_ECM2));
1828
1829
1830 % ECM-GARCH: Spot and Fut18
1831 GARCH2 = garch('GARCHlags', 1, 'ARCHlags', 1)
1832 [estMdl, estParamCov, logL] = estimate(GARCH2, ECM2.Spot_firstdiff)
1833 condVar_2 = infer(estMdl, ECM2.Spot_firstdiff);
1834 ECM2.condVol = sqrt(condVar_2);
1835
1836 ECM_GARCH2 = fitlm(ECM2, ['Spot_firstdiff ~ LaggedResiduals +
    Fut18_firstdiff_lag1 + Fut18_firstdiff_lag2' ...
1837     '+ Fut18_firstdiff_lag3 + Fut18_firstdiff_lag4 + Fut18_firstdiff_lag5
    + Fut18_firstdiff_lag6' ...
1838     '+ Fut18_firstdiff_lag7 + Fut18_firstdiff_lag8 + Spot_firstdiff_lag1
    + Spot_firstdiff_lag2' ...
1839     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
1840     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + condVol'])
1841
1842 Pred18 = forecast(estMdl, height(residuals_2), 'Y0', ECM2.Spot_firstdiff)
    ;
1843 Pred18_Vol = sqrt(Pred18);
1844
1845
1846 Predicted_SpotFD_GARCH2 = [ECM_GARCH2.Coefficients.Estimate(1) +
    ECM_GARCH2.Coefficients.Estimate(3)*data.Fut18_firstdiff_lag1
    (1215:1460) ...
1847     + ECM_GARCH2.Coefficients.Estimate(4)*data.Fut18_firstdiff_lag2

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(1215:1460) + ECM_GARCH2.Coefficients.Estimate(5)*data.
  Fut18_firstdiff_lag3(1215:1460) ...
1848 + ECM_GARCH2.Coefficients.Estimate(6)*data.Fut18_firstdiff_lag4
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(7)*data.
  Fut18_firstdiff_lag5(1215:1460) ...
1849 + ECM_GARCH2.Coefficients.Estimate(8)*data.Fut18_firstdiff_lag6
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(9)*data.
  Fut18_firstdiff_lag7(1215:1460) ...
1850 + ECM_GARCH2.Coefficients.Estimate(10)*data.Fut18_firstdiff_lag8
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(11)*data.
  Spot_firstdiff_lag1(1215:1460) ...
1851 + ECM_GARCH2.Coefficients.Estimate(12)*data.Spot_firstdiff_lag2
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(13)*data.
  Spot_firstdiff_lag3(1215:1460) ...
1852 + ECM_GARCH2.Coefficients.Estimate(14)*data.Spot_firstdiff_lag4
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(15)*data.
  Spot_firstdiff_lag5(1215:1460) ...
1853 + ECM_GARCH2.Coefficients.Estimate(16)*data.Spot_firstdiff_lag6
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(17)*data.
  Spot_firstdiff_lag7(1215:1460) ...
1854 + ECM_GARCH2.Coefficients.Estimate(18)*data.Spot_firstdiff_lag8
(1215:1460) + ECM_GARCH2.Coefficients.Estimate(2)*residuals_2.
  LaggedResiduals ...
1855 + ECM_GARCH2.Coefficients.Estimate(19)*Pred18_Vol];
1856
1857 Predictions_GARCH2 = table();
1858 Predictions_GARCH2.Date = data.Date(1214:1460);
1859 Predictions_GARCH2.Spot = data.Spot(1214:1460);
1860 Predictions_GARCH2.PredictedSpotFD = zeros(247,1);
1861 Predictions_GARCH2.PredictedSpotFD(2:end) = Predicted_SpotFD_GARCH2;
1862 Predictions_GARCH2.PredictedSpot = lagmatrix(Predictions_GARCH2.Spot, 1)
  + Predictions_GARCH2.PredictedSpotFD;
1863 Predictions_GARCH2(1,:) = [];
1864 Predictions_GARCH2.Spot = exp(Predictions_GARCH2.Spot);
1865 Predictions_GARCH2.PredictedSpot = exp(Predictions_GARCH2.PredictedSpot);
1866 Predictions_GARCH2(242:end,:) = [];
1867
1868 MSE_GARCH2 = (sum(Predictions_GARCH2.PredictedSpot - Predictions_GARCH2.
  Spot)^2)/(239);
1869 RMSE_GARCH2 = sqrt(MSE_GARCH2)
1870
1871 ChangePred_GARCH2 = Predictions_GARCH2.PredictedSpot - lagmatrix(
  Predictions_GARCH2.PredictedSpot, 1);
1872 ChangeSpot_GARCH2 = Predictions_GARCH2.Spot - lagmatrix(
  Predictions_GARCH2.Spot, 1);
1873
1874 SignPred_GARCH2 = table();
1875 for i = 1:height(Predictions_GARCH2)
1876     if ChangePred_GARCH2(i) >= 0 & ChangeSpot_GARCH2(i) >= 0
1877         SignPred_GARCH2.True(i) = 1;
1878     else
1879         SignPred_GARCH2.True(i) = 0;
1880     end
1881 end
1882
1883 for i = 1:239
1884     if ChangePred_GARCH2(i) <= 0 & ChangeSpot_GARCH2(i) <= 0
1885         SignPred_GARCH2.True1(i) = 1;
1886     else
1887         SignPred_GARCH2.True1(i) = 0;
1888     end

```

```

1889 end
1890
1891 PercentCorrect_GARCH2 = (sum(SignPred_GARCH2.True) + sum(SignPred_GARCH2.
    True1)) / (height(Predictions_GARCH2));
1892
1893
1894 % Finding residuals between Spot and lagged Fut17:
1895 reg3 = table();
1896 reg3.Date = data.Date(1:990);
1897 reg3.Spot = data.Spot(1:990);
1898 reg3.LagFut17 = lagmatrix(data.Fut17(1:990),1);
1899 reg3(1,:) = [];
1900 model3 = fitlm(reg3, 'Spot ~ LagFut17')
1901 reg3.residuals3 = model3.Residuals.Raw;
1902
1903 % Defining ECM variables – Spot and Fut18:
1904 ECM3 = table();
1905 ECM3.Date = reg3.Date;
1906 ECM3.Spot_firstdiff = data.Spot_firstdiff(2:990);
1907 ECM3.LaggedResiduals = lagmatrix(reg3.residuals3,1);
1908 %Lag variables Fut17:
1909 ECM3.Fut17_firstdiff_lag1 = reg3.LagFut17 - lagmatrix(reg3.LagFut17,1);
1910 ECM3.Fut17_firstdiff_lag2 = lagmatrix(ECM3.Fut17_firstdiff_lag1,1);
1911 ECM3.Fut17_firstdiff_lag3 = lagmatrix(ECM3.Fut17_firstdiff_lag1,2);
1912 ECM3.Fut17_firstdiff_lag4 = lagmatrix(ECM3.Fut17_firstdiff_lag1,3);
1913 ECM3.Fut17_firstdiff_lag5 = lagmatrix(ECM3.Fut17_firstdiff_lag1,4);
1914 ECM3.Fut17_firstdiff_lag6 = lagmatrix(ECM3.Fut17_firstdiff_lag1,5);
1915 ECM3.Fut17_firstdiff_lag7 = lagmatrix(ECM3.Fut17_firstdiff_lag1,6);
1916 ECM3.Fut17_firstdiff_lag8 = lagmatrix(ECM3.Fut17_firstdiff_lag1,7);
1917 ECM3.Fut17_firstdiff_lag9 = lagmatrix(ECM3.Fut17_firstdiff_lag1,8);
1918 ECM3.Fut17_firstdiff_lag10 = lagmatrix(ECM3.Fut17_firstdiff_lag1,9);
1919 ECM3.Fut17_firstdiff_lag11 = lagmatrix(ECM3.Fut17_firstdiff_lag1,10);
1920 ECM3.Fut17_firstdiff_lag12 = lagmatrix(ECM3.Fut17_firstdiff_lag1,11);
1921
1922 %Lag variables spot:
1923 ECM3.Spot_firstdiff_lag1 = lagmatrix(ECM3.Spot_firstdiff,1);
1924 ECM3.Spot_firstdiff_lag2 = lagmatrix(ECM3.Spot_firstdiff,2);
1925 ECM3.Spot_firstdiff_lag3 = lagmatrix(ECM3.Spot_firstdiff,3);
1926 ECM3.Spot_firstdiff_lag4 = lagmatrix(ECM3.Spot_firstdiff,4);
1927 ECM3.Spot_firstdiff_lag5 = lagmatrix(ECM3.Spot_firstdiff,5);
1928 ECM3.Spot_firstdiff_lag6 = lagmatrix(ECM3.Spot_firstdiff,6);
1929 ECM3.Spot_firstdiff_lag7 = lagmatrix(ECM3.Spot_firstdiff,7);
1930 ECM3.Spot_firstdiff_lag8 = lagmatrix(ECM3.Spot_firstdiff,8);
1931 ECM3.Spot_firstdiff_lag9 = lagmatrix(ECM3.Spot_firstdiff,9);
1932 ECM3.Spot_firstdiff_lag10 = lagmatrix(ECM3.Spot_firstdiff,10);
1933 ECM3.Spot_firstdiff_lag11 = lagmatrix(ECM3.Spot_firstdiff,11);
1934 ECM3.Spot_firstdiff_lag12 = lagmatrix(ECM3.Spot_firstdiff,12);
1935
1936 ECM3 = fitlm(ECM3, ['Spot_firstdiff ~ LaggedResiduals +
    Fut17_firstdiff_lag1 + Fut17_firstdiff_lag2' ...
1937     '+ Fut17_firstdiff_lag3 + Fut17_firstdiff_lag4 + Fut17_firstdiff_lag5
    + Fut17_firstdiff_lag6' ...
1938     '+ Fut17_firstdiff_lag7 + Fut17_firstdiff_lag8 + Fut17_firstdiff_lag9
    + Fut17_firstdiff_lag10' ...
1939     '+ Fut17_firstdiff_lag11 + Fut17_firstdiff_lag12 +
    Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
1940     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
1941     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
    Spot_firstdiff_lag10' ...
1942     '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12'])

```

```

1943
1944 residuals_3 = table();
1945 residuals_3.Date = data.Date;
1946 residuals_3.LaggedResiduals = zeros(1709,1);
1947
1948 for i = 990:1214
1949     reg = table();
1950     reg.Date = data.Date(1:i);
1951     reg.Spot = data.Spot(1:i);
1952     reg.LagFut17 = lagmatrix(data.Fut17(1:i),1);
1953     reg(1,:) = [];
1954     model = fitlm(reg, 'Spot ~ LagFut17');
1955     reg.residuals = model.Residuals.Raw;
1956     residuals_3.LaggedResiduals(i+1) = reg.residuals(end);
1957 end
1958
1959 residuals_3(1:990,:) = [];
1960 residuals_3(225:end,:) = [];
1961
1962
1963 Predicted_SpotFD_ECM3 = [ECM3.Coefficients.Estimate(1) + ECM3.
    Coefficients.Estimate(3)*data.Fut17_firstdiff_lag1(991:1214) ...
1964     + ECM3.Coefficients.Estimate(4)*data.Fut17_firstdiff_lag2(991:1214)
        + ECM3.Coefficients.Estimate(5)*data.Fut17_firstdiff_lag3
        (991:1214) ...
1965     + ECM3.Coefficients.Estimate(6)*data.Fut17_firstdiff_lag4(991:1214)
        + ECM3.Coefficients.Estimate(7)*data.Fut17_firstdiff_lag5
        (991:1214) ...
1966     + ECM3.Coefficients.Estimate(8)*data.Fut17_firstdiff_lag6(991:1214)
        + ECM3.Coefficients.Estimate(9)*data.Fut17_firstdiff_lag7
        (991:1214) ...
1967     + ECM3.Coefficients.Estimate(10)*data.Fut17_firstdiff_lag8(991:1214)
        + ECM3.Coefficients.Estimate(11)*data.Fut17_firstdiff_lag9
        (991:1214) ...
1968     + ECM3.Coefficients.Estimate(12)*data.Fut17_firstdiff_lag10
        (991:1214) + ECM3.Coefficients.Estimate(13)*data.
        Fut17_firstdiff_lag11(991:1214) ...
1969     + ECM3.Coefficients.Estimate(14)*data.Fut17_firstdiff_lag12
        (991:1214) + ECM3.Coefficients.Estimate(15)*data.
        Spot_firstdiff_lag1(991:1214) ...
1970     + ECM3.Coefficients.Estimate(16)*data.Spot_firstdiff_lag2(991:1214)
        + ECM3.Coefficients.Estimate(17)*data.Spot_firstdiff_lag3
        (991:1214) ...
1971     + ECM3.Coefficients.Estimate(18)*data.Spot_firstdiff_lag4(991:1214)
        + ECM3.Coefficients.Estimate(19)*data.Spot_firstdiff_lag5
        (991:1214) ...
1972     + ECM3.Coefficients.Estimate(20)*data.Spot_firstdiff_lag6(991:1214)
        + ECM3.Coefficients.Estimate(21)*data.Spot_firstdiff_lag7
        (991:1214) ...
1973     + ECM3.Coefficients.Estimate(22)*data.Spot_firstdiff_lag8(991:1214)
        + ECM3.Coefficients.Estimate(23)*data.Spot_firstdiff_lag9
        (991:1214) ...
1974     + ECM3.Coefficients.Estimate(24)*data.Spot_firstdiff_lag10(991:1214)
        + ECM3.Coefficients.Estimate(25)*data.Spot_firstdiff_lag11
        (991:1214) ...
1975     + ECM3.Coefficients.Estimate(26)*data.Spot_firstdiff_lag12(991:1214)
        + ECM3.Coefficients.Estimate(2)*residuals_3.LaggedResiduals];
1976
1977
1978 Predictions_ECM3 = table();
1979 Predictions_ECM3.Date = data.Date(990:1214);

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```

1980 Predictions_ECM3.Spot = data.Spot(990:1214);
1981 Predictions_ECM3.PredictedSpotFD = zeros(225,1);
1982 Predictions_ECM3.PredictedSpotFD(2:end) = Predicted_SpotFD_ECM3;
1983 Predictions_ECM3.PredictedSpot = lagmatrix(Predictions_ECM3.Spot, 1) +
    Predictions_ECM3.PredictedSpotFD;
1984 Predictions_ECM3(1,:) = [];
1985 Predictions_ECM3.Spot = exp(Predictions_ECM3.Spot);
1986 Predictions_ECM3.PredictedSpot = exp(Predictions_ECM3.PredictedSpot);
1987 Predictions_ECM3(219:end,:) = [];
1988
1989 MSE_ECM3 = (sum(Predictions_ECM3.PredictedSpot - Predictions_ECM3.Spot)
    ^2)/(218);
1990 RMSE_ECM3 = sqrt(MSE_ECM3)
1991
1992 ChangePred_ECM3 = Predictions_ECM3.PredictedSpot - lagmatrix(
    Predictions_ECM3.PredictedSpot, 1);
1993 ChangeSpot_ECM3 = Predictions_ECM3.Spot - lagmatrix(Predictions_ECM3.Spot
    , 1);
1994
1995 SignPred_ECM3 = table();
1996 for i = 1:height(Predictions_ECM3)
1997     if ChangePred_ECM3(i) >= 0 & ChangeSpot_ECM3(i) >= 0
1998         SignPred_ECM3.True(i) = 1;
1999     else
2000         SignPred_ECM3.True(i) = 0;
2001     end
2002 end
2003
2004 for i = 1:height(Predictions_ECM3)
2005     if ChangePred_ECM3(i) <= 0 & ChangeSpot_ECM3(i) <= 0
2006         SignPred_ECM3.True1(i) = 1;
2007     else
2008         SignPred_ECM3.True1(i) = 0;
2009     end
2010 end
2011
2012 PercentCorrect_ECM3 = (sum(SignPred_ECM3.True) + sum(SignPred_ECM3.True1)
    ) / (height(Predictions_ECM3));
2013
2014
2015 % ECM-GARCH: Spot and Fut17
2016 GARCH3 = garch('GARCHlags', 1, 'ARCHlags', 1)
2017 [estMdl, estParamCov, logL] = estimate(GARCH3, ECM3.Spot_firstdiff)
2018 condVar_3 = infer(estMdl, ECM3.Spot_firstdiff);
2019 ECM3.condVol = sqrt(condVar_3);
2020
2021 ECM_GARCH3 = fitlm(ECM3, ['Spot_firstdiff ~ LaggedResiduals +
    Fut17_firstdiff_lag1 + Fut17_firstdiff_lag2' ...
2022     '+ Fut17_firstdiff_lag3 + Fut17_firstdiff_lag4 + Fut17_firstdiff_lag5
    + Fut17_firstdiff_lag6' ...
2023     '+ Fut17_firstdiff_lag7 + Fut17_firstdiff_lag8 + Fut17_firstdiff_lag9
    + Fut17_firstdiff_lag10' ...
2024     '+ Fut17_firstdiff_lag11 + Fut17_firstdiff_lag12 +
    Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
2025     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
2026     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
    Spot_firstdiff_lag10' ...
2027     '+ Spot_firstdiff_lag11 + Spot_firstdiff_lag12 + condVol'])
2028
2029 Pred17 = forecast(estMdl, height(residuals_3), 'Y0', ECM3.Spot_firstdiff)

```



```

;
2030 Pred17_Vol = sqrt(Pred17);
2031
2032
2033 Predicted_SpotFD_GARCH3 = [ECM_GARCH3.Coefficients.Estimate(1) +
    ECM_GARCH3.Coefficients.Estimate(3)*data.Fut17_firstdiff_lag1
    (991:1214) ...
2034 + ECM_GARCH3.Coefficients.Estimate(4)*data.Fut17_firstdiff_lag2
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(5)*data.
    Fut17_firstdiff_lag3(991:1214) ...
2035 + ECM_GARCH3.Coefficients.Estimate(6)*data.Fut17_firstdiff_lag4
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(7)*data.
    Fut17_firstdiff_lag5(991:1214) ...
2036 + ECM_GARCH3.Coefficients.Estimate(8)*data.Fut17_firstdiff_lag6
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(9)*data.
    Fut17_firstdiff_lag7(991:1214) ...
2037 + ECM_GARCH3.Coefficients.Estimate(10)*data.Fut17_firstdiff_lag8
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(11)*data.
    Fut17_firstdiff_lag9(991:1214) ...
2038 + ECM_GARCH3.Coefficients.Estimate(12)*data.Fut17_firstdiff_lag10
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(13)*data.
    Fut17_firstdiff_lag11(991:1214) ...
2039 + ECM_GARCH3.Coefficients.Estimate(14)*data.Fut17_firstdiff_lag12
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(15)*data.
    Spot_firstdiff_lag1(991:1214) ...
2040 + ECM_GARCH3.Coefficients.Estimate(16)*data.Spot_firstdiff_lag2
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(17)*data.
    Spot_firstdiff_lag3(991:1214) ...
2041 + ECM_GARCH3.Coefficients.Estimate(18)*data.Spot_firstdiff_lag4
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(19)*data.
    Spot_firstdiff_lag5(991:1214) ...
2042 + ECM_GARCH3.Coefficients.Estimate(20)*data.Spot_firstdiff_lag6
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(21)*data.
    Spot_firstdiff_lag7(991:1214) ...
2043 + ECM_GARCH3.Coefficients.Estimate(22)*data.Spot_firstdiff_lag8
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(23)*data.
    Spot_firstdiff_lag9(991:1214) ...
2044 + ECM_GARCH3.Coefficients.Estimate(24)*data.Spot_firstdiff_lag10
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(25)*data.
    Spot_firstdiff_lag11(991:1214) ...
2045 + ECM_GARCH3.Coefficients.Estimate(26)*data.Spot_firstdiff_lag12
    (991:1214) + ECM_GARCH3.Coefficients.Estimate(2)*residuals_3.
    LaggedResiduals ...
2046 + ECM_GARCH3.Coefficients.Estimate(27)*Pred17_Vol];
2047
2048 Predictions_GARCH3 = table();
2049 Predictions_GARCH3.Date = data.Date(990:1214);
2050 Predictions_GARCH3.Spot = data.Spot(990:1214);
2051 Predictions_GARCH3.PredictedSpotFD = zeros(225,1);
2052 Predictions_GARCH3.PredictedSpotFD(2:end) = Predicted_SpotFD_GARCH3;
2053 Predictions_GARCH3.PredictedSpot = lagmatrix(Predictions_GARCH3.Spot, 1)
    + Predictions_GARCH3.PredictedSpotFD;
2054 Predictions_GARCH3(1,:) = [];
2055 Predictions_GARCH3.Spot = exp(Predictions_GARCH3.Spot);
2056 Predictions_GARCH3.PredictedSpot = exp(Predictions_GARCH3.PredictedSpot);
2057 Predictions_GARCH3(219:end,:) = [];
2058
2059 MSE_GARCH3 = (sum(Predictions_GARCH3.PredictedSpot - Predictions_GARCH3.
    Spot)^2)/(218);
2060 RMSE_GARCH3 = sqrt(MSE_GARCH3)
2061

```

```

2062 ChangePred_GARCH3 = Predictions_GARCH3.PredictedSpot - lagmatrix(
    Predictions_GARCH3.PredictedSpot, 1);
2063 ChangeSpot_GARCH3 = Predictions_GARCH3.Spot - lagmatrix(
    Predictions_GARCH3.Spot, 1);
2064
2065 SignPred_GARCH3 = table();
2066 for i = 1:height(Predictions_GARCH3)
2067     if ChangePred_GARCH3(i) >= 0 & ChangeSpot_GARCH3(i) >= 0
2068         SignPred_GARCH3.True(i) = 1;
2069     else
2070         SignPred_GARCH3.True(i) = 0;
2071     end
2072 end
2073
2074 for i = 1:height(Predictions_GARCH3)
2075     if ChangePred_GARCH3(i) <= 0 & ChangeSpot_GARCH3(i) <= 0
2076         SignPred_GARCH3.True1(i) = 1;
2077     else
2078         SignPred_GARCH3.True1(i) = 0;
2079     end
2080 end
2081 PercentCorrect_GARCH3 = (sum(SignPred_GARCH3.True) + sum(SignPred_GARCH3.
    True1)) / (height(Predictions_GARCH3));
2082
2083
2084 % Finding residuals between Spot and lagged Fut16:
2085 reg4 = table();
2086 reg4.Date = data.Date(1:739);
2087 reg4.Spot = data.Spot(1:739);
2088 reg4.LagFut16 = lagmatrix(data.Fut16(1:739),1);
2089 reg4(1,:) = [];
2090 model4 = fitlm(reg4, 'Spot ~ LagFut16')
2091 reg4.residuals4 = model4.Residuals.Raw;
2092
2093 % Defining ECM variables - Spot and Fut16:
2094 ECM4 = table();
2095 ECM4.Date = reg4.Date;
2096 ECM4.Spot_firstdiff = data.Spot_firstdiff(2:739);
2097 ECM4.LaggedResiduals = lagmatrix(reg4.residuals4,1);
2098 %Lag variables - Fut:
2099 ECM4.Fut16_firstdiff_lag1 = reg4.LagFut16 - lagmatrix(reg4.LagFut16,1);
2100 ECM4.Fut16_firstdiff_lag2 = lagmatrix(ECM4.Fut16_firstdiff_lag1,1);
2101 ECM4.Fut16_firstdiff_lag3 = lagmatrix(ECM4.Fut16_firstdiff_lag1,2);
2102 ECM4.Fut16_firstdiff_lag4 = lagmatrix(ECM4.Fut16_firstdiff_lag1,3);
2103 ECM4.Fut16_firstdiff_lag5 = lagmatrix(ECM4.Fut16_firstdiff_lag1,4);
2104 ECM4.Fut16_firstdiff_lag6 = lagmatrix(ECM4.Fut16_firstdiff_lag1,5);
2105 ECM4.Fut16_firstdiff_lag7 = lagmatrix(ECM4.Fut16_firstdiff_lag1,6);
2106
2107
2108 %Lag variables spot:
2109 ECM4.Spot_firstdiff_lag1 = lagmatrix(ECM4.Spot_firstdiff,1);
2110 ECM4.Spot_firstdiff_lag2 = lagmatrix(ECM4.Spot_firstdiff,2);
2111 ECM4.Spot_firstdiff_lag3 = lagmatrix(ECM4.Spot_firstdiff,3);
2112 ECM4.Spot_firstdiff_lag4 = lagmatrix(ECM4.Spot_firstdiff,4);
2113 ECM4.Spot_firstdiff_lag5 = lagmatrix(ECM4.Spot_firstdiff,5);
2114 ECM4.Spot_firstdiff_lag6 = lagmatrix(ECM4.Spot_firstdiff,6);
2115 ECM4.Spot_firstdiff_lag7 = lagmatrix(ECM4.Spot_firstdiff,7);
2116
2117
2118
2119 ECM4 = fitlm(ECM4, ['Spot_firstdiff ~ LaggedResiduals +

```



```

2120     'Fut16_firstdiff_lag1 + Fut16_firstdiff_lag2' ...
2121     '+ Fut16_firstdiff_lag3 + Fut16_firstdiff_lag4 + Fut16_firstdiff_lag5
2122     + Fut16_firstdiff_lag6' ...
2123     '+ Fut16_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'
2124     ...
2125     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
2126     Spot_firstdiff_lag6' ...
2127     '+ Spot_firstdiff_lag7']])
2128
2129 residuals_4 = table();
2130 residuals_4.Date = data.Date;
2131 residuals_4.LaggedResiduals = zeros(1709,1);
2132
2133 for i = 739:990
2134     reg = table();
2135     reg.Date = data.Date(1:i);
2136     reg.Spot = data.Spot(1:i);
2137     reg.LagFut16 = lagmatrix(data.Fut16(1:i),1);
2138     reg(1,:) = [];
2139     model4 = fitlm(reg, 'Spot ~ LagFut16');
2140     reg.residuals = model4.Residuals.Raw;
2141     residuals_4.LaggedResiduals(i+1) = reg.residuals(end);
2142 end
2143
2144 residuals_4(1:739,:) = [];
2145 residuals_4(252:end,:) = [];
2146
2147 Predicted_SpotFD_ECM4 = [ECM4.Coefficients.Estimate(1) + ECM4.
2148     Coefficients.Estimate(3)*data.Fut16_firstdiff_lag1(740:990) ...
2149     + ECM4.Coefficients.Estimate(4)*data.Fut16_firstdiff_lag2(740:990) +
2150     ECM4.Coefficients.Estimate(5)*data.Fut16_firstdiff_lag3(740:990)
2151     ...
2152     + ECM4.Coefficients.Estimate(6)*data.Fut16_firstdiff_lag4(740:990) +
2153     ECM4.Coefficients.Estimate(7)*data.Fut16_firstdiff_lag5(740:990)
2154     ...
2155     + ECM4.Coefficients.Estimate(8)*data.Fut16_firstdiff_lag6(740:990) +
2156     ECM4.Coefficients.Estimate(9)*data.Fut16_firstdiff_lag7(740:990)
2157     ...
2158     + ECM4.Coefficients.Estimate(10)*data.Spot_firstdiff_lag1(740:990) +
2159     ECM4.Coefficients.Estimate(11)*data.Spot_firstdiff_lag2(740:990)
2160     ...
2161     + ECM4.Coefficients.Estimate(12)*data.Spot_firstdiff_lag3(740:990) +
2162     ECM4.Coefficients.Estimate(13)*data.Spot_firstdiff_lag4(740:990)
2163     ...
2164     + ECM4.Coefficients.Estimate(14)*data.Spot_firstdiff_lag5(740:990) +
2165     ECM4.Coefficients.Estimate(15)*data.Spot_firstdiff_lag6(740:990)
2166     ...
2167     + ECM4.Coefficients.Estimate(16)*data.Spot_firstdiff_lag7(740:990) +
2168     ECM4.Coefficients.Estimate(2)*residuals_4.LaggedResiduals];
2169
2170 Predictions_ECM4 = table();
2171 Predictions_ECM4.Date = data.Date(739:990);
2172 Predictions_ECM4.Spot = data.Spot(739:990);
2173 Predictions_ECM4.PredictedSpotFD = zeros(252,1);
2174 Predictions_ECM4.PredictedSpotFD(2:end) = Predicted_SpotFD_ECM4;
2175 Predictions_ECM4.PredictedSpot = lagmatrix(Predictions_ECM4.Spot, 1) +
2176     Predictions_ECM4.PredictedSpotFD;
2177 Predictions_ECM4(1,:) = [];
2178 Predictions_ECM4.Spot = exp(Predictions_ECM4.Spot);
2179 Predictions_ECM4.PredictedSpot = exp(Predictions_ECM4.PredictedSpot);
2180 Predictions_ECM4(246:end,:) = [];

```

```

2162
2163 MSE_ECM4 = (sum(Predictions_ECM4.PredictedSpot - Predictions_ECM4.Spot)
      ^2)/(245);
2164 RMSE_ECM4 = sqrt(MSE_ECM4)
2165
2166 ChangePred_ECM4 = Predictions_ECM4.PredictedSpot - lagmatrix(
      Predictions_ECM4.PredictedSpot, 1);
2167 ChangeSpot_ECM4 = Predictions_ECM4.Spot - lagmatrix(Predictions_ECM4.Spot
      , 1);
2168
2169 SignPred_ECM4 = table();
2170 for i = 1:height(Predictions_ECM4)
2171     if ChangePred_ECM4(i) >= 0 & ChangeSpot_ECM4(i) >= 0
2172         SignPred_ECM4.True(i) = 1;
2173     else
2174         SignPred_ECM4.True(i) = 0;
2175     end
2176 end
2177
2178 for i = 1:height(Predictions_ECM4)
2179     if ChangePred_ECM4(i) <= 0 & ChangeSpot_ECM4(i) <= 0
2180         SignPred_ECM4.True1(i) = 1;
2181     else
2182         SignPred_ECM4.True1(i) = 0;
2183     end
2184 end
2185
2186 PercentCorrect_ECM4 = (sum(SignPred_ECM4.True) + sum(SignPred_ECM4.True1)
      ) / (height(Predictions_ECM4));
2187
2188
2189 % ECM-GARCH: Spot and Fut16
2190 GARCH4 = garch('GARCHlags', 1, 'ARCHlags', 1)
2191 [estMdl, estParamCov, logL] = estimate(GARCH4, ECM4.Spot_firstdiff)
2192 condVar_4 = infer(estMdl, ECM4.Spot_firstdiff);
2193 ECM4.condVol = sqrt(condVar_4);
2194
2195 ECM_GARCH4 = fitlm(ECM4, ['Spot_firstdiff ~ LaggedResiduals +
      Fut16_firstdiff_lag1 + Fut16_firstdiff_lag2' ...
2196     '+ Fut16_firstdiff_lag3 + Fut16_firstdiff_lag4 + Fut16_firstdiff_lag5
      + Fut16_firstdiff_lag6' ...
2197     '+ Fut16_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'
      ...
2198     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
      Spot_firstdiff_lag6' ...
2199     '+ Spot_firstdiff_lag7 + condVol'])
2200
2201 Pred16 = forecast(estMdl, height(residuals_4), 'Y0', ECM4.Spot_firstdiff)
      ;
2202 Pred16_Vol = sqrt(Pred16);
2203
2204
2205 Predicted_SpotFD_GARCH4 = [ECM_GARCH4.Coefficients.Estimate(1) +
      ECM_GARCH4.Coefficients.Estimate(3)*data.Fut16_firstdiff_lag1
      (740:990) ...
2206     + ECM_GARCH4.Coefficients.Estimate(4)*data.Fut16_firstdiff_lag2
      (740:990) + ECM_GARCH4.Coefficients.Estimate(5)*data.
      Fut16_firstdiff_lag3(740:990) ...
2207     + ECM_GARCH4.Coefficients.Estimate(6)*data.Fut16_firstdiff_lag4
      (740:990) + ECM_GARCH4.Coefficients.Estimate(7)*data.
      Fut16_firstdiff_lag5(740:990) ...

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```

2208 + ECM_GARCH4.Coefficients.Estimate(8)*data.Fut16_firstdiff_lag6
      (740:990) + ECM_GARCH4.Coefficients.Estimate(9)*data.
      Fut16_firstdiff_lag7(740:990) ...
2209 + ECM_GARCH4.Coefficients.Estimate(10)*data.Spot_firstdiff_lag1
      (740:990) + ECM_GARCH4.Coefficients.Estimate(11)*data.
      Spot_firstdiff_lag2(740:990) ...
2210 + ECM_GARCH4.Coefficients.Estimate(12)*data.Spot_firstdiff_lag3
      (740:990) + ECM_GARCH4.Coefficients.Estimate(13)*data.
      Spot_firstdiff_lag4(740:990) ...
2211 + ECM_GARCH4.Coefficients.Estimate(14)*data.Spot_firstdiff_lag5
      (740:990) + ECM_GARCH4.Coefficients.Estimate(15)*data.
      Spot_firstdiff_lag6(740:990) ...
2212 + ECM_GARCH4.Coefficients.Estimate(16)*data.Spot_firstdiff_lag7
      (740:990) + ECM_GARCH4.Coefficients.Estimate(2)*residuals_4.
      LaggedResiduals ...
2213 + ECM_GARCH4.Coefficients.Estimate(17)*Pred16_Vol];
2214
2215 Predictions_GARCH4 = table();
2216 Predictions_GARCH4.Date = data.Date(739:990);
2217 Predictions_GARCH4.Spot = data.Spot(739:990);
2218 Predictions_GARCH4.PredictedSpotFD = zeros(252,1);
2219 Predictions_GARCH4.PredictedSpotFD(2:end) = Predicted_SpotFD_GARCH4;
2220 Predictions_GARCH4.PredictedSpot = lagmatrix(Predictions_GARCH4.Spot, 1)
      + Predictions_GARCH4.PredictedSpotFD;
2221 Predictions_GARCH4(1,:) = [];
2222 Predictions_GARCH4.Spot = exp(Predictions_GARCH4.Spot);
2223 Predictions_GARCH4.PredictedSpot = exp(Predictions_GARCH4.PredictedSpot);
2224 Predictions_GARCH4(246:end,:) = [];
2225
2226 MSE_GARCH4 = (sum(Predictions_GARCH4.PredictedSpot - Predictions_GARCH4.
      Spot)^2)/(245);
2227 RMSE_GARCH4 = sqrt(MSE_GARCH4)
2228
2229 ChangePred_GARCH4 = Predictions_GARCH4.PredictedSpot - lagmatrix(
      Predictions_GARCH4.PredictedSpot, 1);
2230 ChangeSpot_GARCH4 = Predictions_GARCH4.Spot - lagmatrix(
      Predictions_GARCH4.Spot, 1);
2231
2232 SignPred_GARCH4 = table();
2233 for i = 1:height(Predictions_GARCH4)
2234     if ChangePred_GARCH4(i) >= 0 & ChangeSpot_GARCH4(i) >= 0
2235         SignPred_GARCH4.True(i) = 1;
2236     else
2237         SignPred_GARCH4.True(i) = 0;
2238     end
2239 end
2240
2241 for i = 1:height(Predictions_GARCH4)
2242     if ChangePred_GARCH4(i) <= 0 & ChangeSpot_GARCH4(i) <= 0
2243         SignPred_GARCH4.True1(i) = 1;
2244     else
2245         SignPred_GARCH4.True1(i) = 0;
2246     end
2247 end
2248 PercentCorrect_GARCH4 = (sum(SignPred_GARCH4.True) + sum(SignPred_GARCH4.
      True1)) / (height(Predictions_GARCH4));
2249
2250 % Finding residuals between Spot and lagged Fut16:
2251 reg5 = table();
2252 reg5.Date = data.Date(1:493);
2253 reg5.Spot = data.Spot(1:493);

```

```

2254 reg5.LagFut15 = lagmatrix(data.Fut15(1:493),1);
2255 reg5(1,:) = [];
2256 model5 = fitlm(reg5, 'Spot ~ LagFut15')
2257 reg5.residuals5 = model5.Residuals.Raw;
2258
2259 % Defining ECM variables – Spot and Fut15:
2260 ECM5 = table();
2261 ECM5.Date = reg5.Date;
2262 ECM5.Spot_firstdiff = data.Spot_firstdiff(2:493);
2263 ECM5.LaggedResiduals = lagmatrix(reg5.residuals5,1);
2264 %Lag variables – Fut:
2265 ECM5.Fut15_firstdiff_lag1 = reg5.LagFut15 – lagmatrix(reg5.LagFut15,1);
2266 ECM5.Fut15_firstdiff_lag2 = lagmatrix(ECM5.Fut15_firstdiff_lag1,1);
2267 ECM5.Fut15_firstdiff_lag3 = lagmatrix(ECM5.Fut15_firstdiff_lag1,2);
2268 ECM5.Fut15_firstdiff_lag4 = lagmatrix(ECM5.Fut15_firstdiff_lag1,3);
2269 ECM5.Fut15_firstdiff_lag5 = lagmatrix(ECM5.Fut15_firstdiff_lag1,4);
2270 ECM5.Fut15_firstdiff_lag6 = lagmatrix(ECM5.Fut15_firstdiff_lag1,5);
2271 ECM5.Fut15_firstdiff_lag7 = lagmatrix(ECM5.Fut15_firstdiff_lag1,6);
2272 ECM5.Fut15_firstdiff_lag8 = lagmatrix(ECM5.Fut15_firstdiff_lag1,7);
2273 ECM5.Fut15_firstdiff_lag9 = lagmatrix(ECM5.Fut15_firstdiff_lag1,8);
2274 ECM5.Fut15_firstdiff_lag10 = lagmatrix(ECM5.Fut15_firstdiff_lag1,9);
2275 %Lag variables spot:
2276 ECM5.Spot_firstdiff_lag1 = lagmatrix(ECM5.Spot_firstdiff,1);
2277 ECM5.Spot_firstdiff_lag2 = lagmatrix(ECM5.Spot_firstdiff,2);
2278 ECM5.Spot_firstdiff_lag3 = lagmatrix(ECM5.Spot_firstdiff,3);
2279 ECM5.Spot_firstdiff_lag4 = lagmatrix(ECM5.Spot_firstdiff,4);
2280 ECM5.Spot_firstdiff_lag5 = lagmatrix(ECM5.Spot_firstdiff,5);
2281 ECM5.Spot_firstdiff_lag6 = lagmatrix(ECM5.Spot_firstdiff,6);
2282 ECM5.Spot_firstdiff_lag7 = lagmatrix(ECM5.Spot_firstdiff,7);
2283 ECM5.Spot_firstdiff_lag8 = lagmatrix(ECM5.Spot_firstdiff,8);
2284 ECM5.Spot_firstdiff_lag9 = lagmatrix(ECM5.Spot_firstdiff,9);
2285 ECM5.Spot_firstdiff_lag10 = lagmatrix(ECM5.Spot_firstdiff,10);
2286
2287 ECM5 = fitlm(ECM5, ['Spot_firstdiff ~ LaggedResiduals +
    Fut15_firstdiff_lag1 + Fut15_firstdiff_lag2' ...
2288     '+ Fut15_firstdiff_lag3 + Fut15_firstdiff_lag4 + Fut15_firstdiff_lag5
    + Fut15_firstdiff_lag6' ...
2289     '+ Fut15_firstdiff_lag7 + Fut15_firstdiff_lag8 + Fut15_firstdiff_lag9
    + Fut15_firstdiff_lag10' ...
2290     '+ Spot_firstdiff_lag1 + Spot_firstdiff_lag2' ...
2291     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
2292     '+ Spot_firstdiff_lag7 + Spot_firstdiff_lag8 + Spot_firstdiff_lag9 +
    Spot_firstdiff_lag10'])
2293
2294 residuals_5 = table();
2295 residuals_5.Date = data.Date;
2296 residuals_5.LaggedResiduals = zeros(1709,1);
2297
2298 for i = 493:739
2299     reg = table();
2300     reg.Date = data.Date(1:i);
2301     reg.Spot = data.Spot(1:i);
2302     reg.LagFut15 = lagmatrix(data.Fut15(1:i),1);
2303     reg(1,:) = [];
2304     model5 = fitlm(reg, 'Spot ~ LagFut15');
2305     reg.residuals = model5.Residuals.Raw;
2306     residuals_5.LaggedResiduals(i+1) = reg.residuals(end);
2307 end
2308
2309 residuals_5(1:493,:) = [];

```

```

2310 residuals_5(247:end,:) = [];
2311
2312 Predicted_SpotFD_ECM5 = [ECM5.Coefficients.Estimate(1) + ECM5.
    Coefficients.Estimate(3)*data.Fut15_firstdiff_lag1(494:739) ...
2313 + ECM5.Coefficients.Estimate(4)*data.Fut15_firstdiff_lag2(494:739) +
    ECM5.Coefficients.Estimate(5)*data.Fut15_firstdiff_lag3(494:739)
    ...
2314 + ECM5.Coefficients.Estimate(6)*data.Fut15_firstdiff_lag4(494:739) +
    ECM5.Coefficients.Estimate(7)*data.Fut15_firstdiff_lag5(494:739)
    ...
2315 + ECM5.Coefficients.Estimate(8)*data.Fut15_firstdiff_lag6(494:739) +
    ECM5.Coefficients.Estimate(9)*data.Fut15_firstdiff_lag7(494:739)
    ...
2316 + ECM5.Coefficients.Estimate(10)*data.Fut15_firstdiff_lag8(494:739)
    + ECM5.Coefficients.Estimate(11)*data.Fut15_firstdiff_lag9
    (494:739) ...
2317 + ECM5.Coefficients.Estimate(12)*data.Fut15_firstdiff_lag10(494:739)
    + ECM5.Coefficients.Estimate(13)*data.Spot_firstdiff_lag1
    (494:739) ...
2318 + ECM5.Coefficients.Estimate(14)*data.Spot_firstdiff_lag2(494:739) +
    ECM5.Coefficients.Estimate(15)*data.Spot_firstdiff_lag3(494:739)
    ...
2319 + ECM5.Coefficients.Estimate(16)*data.Spot_firstdiff_lag4(494:739) +
    ECM5.Coefficients.Estimate(17)*data.Spot_firstdiff_lag5(494:739)
    ...
2320 + ECM5.Coefficients.Estimate(18)*data.Spot_firstdiff_lag6(494:739) +
    ECM5.Coefficients.Estimate(19)*data.Spot_firstdiff_lag7(494:739)
    ...
2321 + ECM5.Coefficients.Estimate(20)*data.Spot_firstdiff_lag8(494:739) +
    ECM5.Coefficients.Estimate(21)*data.Spot_firstdiff_lag9(494:739)
    ...
2322 + ECM5.Coefficients.Estimate(22)*data.Spot_firstdiff_lag10(494:739)+
    ECM5.Coefficients.Estimate(2)*residuals_5.LaggedResiduals];
2323
2324 Predictions_ECM5 = table();
2325 Predictions_ECM5.Date = data.Date(493:739);
2326 Predictions_ECM5.Spot = data.Spot(493:739);
2327 Predictions_ECM5.PredictedSpotFD = zeros(247,1);
2328 Predictions_ECM5.PredictedSpotFD(2:end) = Predicted_SpotFD_ECM5;
2329 Predictions_ECM5.PredictedSpot = lagmatrix(Predictions_ECM5.Spot, 1) +
    Predictions_ECM5.PredictedSpotFD;
2330 Predictions_ECM5(1,:) = [];
2331 Predictions_ECM5.Spot = exp(Predictions_ECM5.Spot);
2332 Predictions_ECM5.PredictedSpot = exp(Predictions_ECM5.PredictedSpot);
2333 Predictions_ECM5(238:end,:) = [];
2334
2335 MSE_ECM5 = (sum(Predictions_ECM5.PredictedSpot - Predictions_ECM5.Spot)
    ^2)/(237);
2336 RMSE_ECM5 = sqrt(MSE_ECM5)
2337
2338 ChangePred_ECM5 = Predictions_ECM5.PredictedSpot - lagmatrix(
    Predictions_ECM5.PredictedSpot, 1);
2339 ChangeSpot_ECM5 = Predictions_ECM5.Spot - lagmatrix(Predictions_ECM5.Spot
    , 1);
2340
2341 SignPred_ECM5 = table();
2342 for i = 1:height(Predictions_ECM5)
2343     if ChangePred_ECM5(i) >= 0 & ChangeSpot_ECM5(i) >= 0
2344         SignPred_ECM5.True(i) = 1;
2345     else
2346         SignPred_ECM5.True(i) = 0;

```

```

2347     end
2348 end
2349
2350 for i = 1:height(Predictions_ECM5)
2351     if ChangePred_ECM5(i) <= 0 & ChangeSpot_ECM5(i) <= 0
2352         SignPred_ECM5.True1(i) = 1;
2353     else
2354         SignPred_ECM5.True1(i) = 0;
2355     end
2356 end
2357
2358 PercentCorrect_ECM5 = (sum(SignPred_ECM5.True) + sum(SignPred_ECM5.True1)
    ) / (height(Predictions_ECM5));
2359
2360
2361
2362 % ECM-GARCH: Spot and Fut16
2363 GARCH5 = garch('GARCHlags', 1, 'ARCHlags', 1)
2364 [estMdl, estParamCov, logL] = estimate(GARCH5, ECM5.Spot_firstdiff)
2365 condVar_5 = infer(estMdl, ECM5.Spot_firstdiff);
2366 ECM5.condVol = sqrt(condVar_5);
2367
2368 ECM.GARCHL5 = fitlm(ECM5, ['Spot_firstdiff ~ LaggedResiduals +
    Fut15_firstdiff_lag1 + Fut15_firstdiff_lag2' ...
2369     '+ Fut15_firstdiff_lag3 + Fut15_firstdiff_lag4 + Fut15_firstdiff_lag5
    + Fut15_firstdiff_lag6' ...
2370     '+ Fut15_firstdiff_lag7 + Fut15_firstdiff_lag8 + Fut15_firstdiff_lag9
    + Fut15_firstdiff_lag10' ...
2371     '+ Spot_firstdiff_lag1 + Spot_firstdiff_lag2 + Spot_firstdiff_lag3 +
    Spot_firstdiff_lag4' ...
2372     '+ Spot_firstdiff_lag5 + Spot_firstdiff_lag6+ Spot_firstdiff_lag7 +
    Spot_firstdiff_lag8' ...
2373     '+ Spot_firstdiff_lag9 + Spot_firstdiff_lag10 + condVol'])
2374
2375 Pred15 = forecast(estMdl, height(residuals_5), 'Y0', ECM5.Spot_firstdiff)
    ;
2376 Pred15_Vol = sqrt(Pred15);
2377
2378
2379 Predicted_SpotFD_GARCH5 = [ECM.GARCHL5.Coefficients.Estimate(1) +
    ECM.GARCHL5.Coefficients.Estimate(3)*data.Fut15_firstdiff_lag1
    (494:739) ...
2380     + ECM.GARCHL5.Coefficients.Estimate(4)*data.Fut15_firstdiff_lag2
    (494:739) + ECM.GARCHL5.Coefficients.Estimate(5)*data.
    Fut15_firstdiff_lag3(494:739) ...
2381     + ECM.GARCHL5.Coefficients.Estimate(6)*data.Fut15_firstdiff_lag4
    (494:739) + ECM.GARCHL5.Coefficients.Estimate(7)*data.
    Fut15_firstdiff_lag5(494:739) ...
2382     + ECM.GARCHL5.Coefficients.Estimate(8)*data.Fut15_firstdiff_lag6
    (494:739) + ECM.GARCHL5.Coefficients.Estimate(9)*data.
    Fut15_firstdiff_lag7(494:739) ...
2383     + ECM.GARCHL5.Coefficients.Estimate(10)*data.Fut15_firstdiff_lag8
    (494:739) + ECM.GARCHL5.Coefficients.Estimate(11)*data.
    Fut15_firstdiff_lag9(494:739) ...
2384     + ECM.GARCHL5.Coefficients.Estimate(12)*data.Fut15_firstdiff_lag10
    (494:739)+ ECM.GARCHL5.Coefficients.Estimate(13)*data.
    Spot_firstdiff_lag1(494:739) ...
2385     + ECM.GARCHL5.Coefficients.Estimate(14)*data.Spot_firstdiff_lag2
    (494:739) + ECM.GARCHL5.Coefficients.Estimate(15)*data.
    Spot_firstdiff_lag3(494:739) ...
2386     + ECM.GARCHL5.Coefficients.Estimate(16)*data.Spot_firstdiff_lag4

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(494:739) + ECM_GARCH5.Coefficients.Estimate(17)*data.
Spot_firstdiff_lag5(494:739) ...
2387 + ECM_GARCH5.Coefficients.Estimate(18)*data.Spot_firstdiff_lag6
(494:739) + ECM_GARCH5.Coefficients.Estimate(19)*data.
Spot_firstdiff_lag7(494:739) ...
2388 + ECM_GARCH5.Coefficients.Estimate(20)*data.Spot_firstdiff_lag8
(494:739) + ECM_GARCH5.Coefficients.Estimate(21)*data.
Spot_firstdiff_lag9(494:739) ...
2389 + ECM_GARCH5.Coefficients.Estimate(22)*data.Spot_firstdiff_lag10
(494:739) + ECM_GARCH5.Coefficients.Estimate(23)*Pred15_Vol + ...
2390 + ECM_GARCH5.Coefficients.Estimate(2)*residuals_5.LaggedResiduals];
2391
2392 Predictions_GARCH5 = table();
2393 Predictions_GARCH5.Date = data.Date(493:739);
2394 Predictions_GARCH5.Spot = data.Spot(493:739);
2395 Predictions_GARCH5.PredictedSpotFD = zeros(247,1);
2396 Predictions_GARCH5.PredictedSpotFD(2:end) = Predicted_SpotFD_GARCH5;
2397 Predictions_GARCH5.PredictedSpot = lagmatrix(Predictions_GARCH5.Spot, 1)
+ Predictions_GARCH5.PredictedSpotFD;
2398 Predictions_GARCH5(1,:) = [];
2399 Predictions_GARCH5.Spot = exp(Predictions_GARCH5.Spot);
2400 Predictions_GARCH5.PredictedSpot = exp(Predictions_GARCH5.PredictedSpot);
2401 Predictions_GARCH5(238:end,:) = [];
2402
2403 MSE_GARCH5 = (sum(Predictions_GARCH5.PredictedSpot - Predictions_GARCH5.
Spot)^2)/(237);
2404 RMSE_GARCH5 = sqrt(MSE_GARCH5)
2405
2406 ChangePred_GARCH5 = Predictions_GARCH5.PredictedSpot - lagmatrix(
Predictions_GARCH5.PredictedSpot, 1);
2407 ChangeSpot_GARCH5 = Predictions_GARCH5.Spot - lagmatrix(
Predictions_GARCH5.Spot, 1);
2408
2409 SignPred_GARCH5 = table();
2410 for i = 1:height(Predictions_GARCH5)
2411     if ChangePred_GARCH5(i) >= 0 & ChangeSpot_GARCH5(i) >= 0
2412         SignPred_GARCH5.True(i) = 1;
2413     else
2414         SignPred_GARCH5.True(i) = 0;
2415     end
2416 end
2417
2418 for i = 1:height(Predictions_GARCH5)
2419     if ChangePred_GARCH5(i) <= 0 & ChangeSpot_GARCH5(i) <= 0
2420         SignPred_GARCH5.True1(i) = 1;
2421     else
2422         SignPred_GARCH5.True1(i) = 0;
2423     end
2424 end
2425 PercentCorrect_GARCH5 = (sum(SignPred_GARCH5.True) + sum(SignPred_GARCH5.
True1)) / (height(Predictions_GARCH5));
2426
2427
2428 % Finding residuals between Spot and lagged Fut14:
2429 reg6 = table();
2430 reg6.Date = data.Date(1:246);
2431 reg6.Spot = data.Spot(1:246);
2432 reg6.LagFut14 = lagmatrix(data.Fut14(1:246),1);
2433 reg6(1,:) = [];
2434 model6 = fitlm(reg6, 'Spot ~ LagFut14')
2435 reg6.residuals6 = model6.Residuals.Raw;

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2436
2437 % Defining ECM variables – Spot and Fut14:
2438 ECM6 = table();
2439 ECM6.Date = reg6.Date;
2440 ECM6.Spot_firstdiff = data.Spot_firstdiff(2:246);
2441 ECM6.LaggedResiduals = lagmatrix(reg6.residuals6,1);
2442 %Lag variables – Fut:
2443 ECM6.Fut14_firstdiff_lag1 = reg6.LagFut14 – lagmatrix(reg6.LagFut14,1);
2444 ECM6.Fut14_firstdiff_lag2 = lagmatrix(ECM6.Fut14_firstdiff_lag1,1);
2445 ECM6.Fut14_firstdiff_lag3 = lagmatrix(ECM6.Fut14_firstdiff_lag1,2);
2446 ECM6.Fut14_firstdiff_lag4 = lagmatrix(ECM6.Fut14_firstdiff_lag1,3);
2447 ECM6.Fut14_firstdiff_lag5 = lagmatrix(ECM6.Fut14_firstdiff_lag1,4);
2448 ECM6.Fut14_firstdiff_lag6 = lagmatrix(ECM6.Fut14_firstdiff_lag1,5);
2449 ECM6.Fut14_firstdiff_lag7 = lagmatrix(ECM6.Fut14_firstdiff_lag1,6);
2450
2451
2452 %Lag variables spot:
2453 ECM6.Spot_firstdiff_lag1 = lagmatrix(ECM6.Spot_firstdiff,1);
2454 ECM6.Spot_firstdiff_lag2 = lagmatrix(ECM6.Spot_firstdiff,2);
2455 ECM6.Spot_firstdiff_lag3 = lagmatrix(ECM6.Spot_firstdiff,3);
2456 ECM6.Spot_firstdiff_lag4 = lagmatrix(ECM6.Spot_firstdiff,4);
2457 ECM6.Spot_firstdiff_lag5 = lagmatrix(ECM6.Spot_firstdiff,5);
2458 ECM6.Spot_firstdiff_lag6 = lagmatrix(ECM6.Spot_firstdiff,6);
2459 ECM6.Spot_firstdiff_lag7 = lagmatrix(ECM6.Spot_firstdiff,7);
2460
2461
2462 ECM_6 = fitlm(ECM6, [ 'Spot_firstdiff ~ LaggedResiduals +
    Fut14_firstdiff_lag1 + Fut14_firstdiff_lag2' ...
2463     '+ Fut14_firstdiff_lag3 + Fut14_firstdiff_lag4 + Fut14_firstdiff_lag5
    + Fut14_firstdiff_lag6' ...
2464     '+ Fut14_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2'
    ...
2465     '+ Spot_firstdiff_lag3 + Spot_firstdiff_lag4 + Spot_firstdiff_lag5 +
    Spot_firstdiff_lag6' ...
2466     '+ Spot_firstdiff_lag7' ])
2467
2468 residuals_6 = table();
2469 residuals_6.Date = data.Date;
2470 residuals_6.LaggedResiduals = zeros(1709,1);
2471
2472 for i = 246:493
2473     reg = table();
2474     reg.Date = data.Date(1:i);
2475     reg.Spot = data.Spot(1:i);
2476     reg.LagFut14 = lagmatrix(data.Fut14(1:i),1);
2477     reg(1,:) = [];
2478     model6 = fitlm(reg, 'Spot ~ LagFut14');
2479     reg.residuals = model6.Residuals.Raw;
2480     residuals_6.LaggedResiduals(i+1) = reg.residuals(end);
2481 end
2482
2483 residuals_6(1:246,:) = [];
2484 residuals_6(248:end,:) = [];
2485
2486 Predicted_SpotFD_ECM6 = [ECM6.Coefficients.Estimate(1) + ECM6.
    Coefficients.Estimate(3)*data.Fut14_firstdiff_lag1(247:493) ...
2487     + ECM6.Coefficients.Estimate(4)*data.Fut14_firstdiff_lag2(247:493) +
    ECM6.Coefficients.Estimate(5)*data.Fut14_firstdiff_lag3(247:493)
    ...
2488     + ECM6.Coefficients.Estimate(6)*data.Fut14_firstdiff_lag4(247:493) +
    ECM6.Coefficients.Estimate(7)*data.Fut14_firstdiff_lag5(247:493)

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2489     + ECM6.Coefficients.Estimate(8)*data.Fut14_firstdiff_lag6(247:493) +
        ECM6.Coefficients.Estimate(9)*data.Fut14_firstdiff_lag7(247:493)
2490     + ECM6.Coefficients.Estimate(10)*data.Spot_firstdiff_lag1(247:493) +
        ECM6.Coefficients.Estimate(11)*data.Spot_firstdiff_lag2(247:493)
2491     + ECM6.Coefficients.Estimate(12)*data.Spot_firstdiff_lag3(247:493) +
        ECM6.Coefficients.Estimate(13)*data.Spot_firstdiff_lag4(247:493)
2492     + ECM6.Coefficients.Estimate(14)*data.Spot_firstdiff_lag5(247:493) +
        ECM6.Coefficients.Estimate(15)*data.Spot_firstdiff_lag6(247:493)
2493     + ECM6.Coefficients.Estimate(16)*data.Spot_firstdiff_lag7(247:493) +
        ECM6.Coefficients.Estimate(2)*residuals_6.LaggedResiduals];
2494
2495 Predictions_ECM6 = table();
2496 Predictions_ECM6.Date = data.Date(246:493);
2497 Predictions_ECM6.Spot = data.Spot(246:493);
2498 Predictions_ECM6.PredictedSpotFD = zeros(248,1);
2499 Predictions_ECM6.PredictedSpotFD(2:end) = Predicted_SpotFD_ECM6;
2500 Predictions_ECM6.PredictedSpot = lagmatrix(Predictions_ECM6.Spot, 1) +
        Predictions_ECM6.PredictedSpotFD;
2501 Predictions_ECM6(1,:) = [];
2502 Predictions_ECM6.Spot = exp(Predictions_ECM6.Spot);
2503 Predictions_ECM6.PredictedSpot = exp(Predictions_ECM6.PredictedSpot);
2504 Predictions_ECM6(241:end,:) = [];
2505
2506 MSE_ECM6 = (sum(Predictions_ECM6.PredictedSpot - Predictions_ECM6.Spot)
        ^2)/(240);
2507 RMSE_ECM6 = sqrt(MSE_ECM6)
2508
2509 ChangePred_ECM6 = Predictions_ECM6.PredictedSpot - lagmatrix(
        Predictions_ECM6.PredictedSpot, 1);
2510 ChangeSpot_ECM6 = Predictions_ECM6.Spot - lagmatrix(Predictions_ECM6.Spot
        , 1);
2511
2512 SignPred_ECM6 = table();
2513 for i = 1:height(Predictions_ECM6)
2514     if ChangePred_ECM6(i) >= 0 & ChangeSpot_ECM6(i) >= 0
2515         SignPred_ECM6.True(i) = 1;
2516     else
2517         SignPred_ECM6.True(i) = 0;
2518     end
2519 end
2520
2521 for i = 1:height(Predictions_ECM6)
2522     if ChangePred_ECM6(i) <= 0 & ChangeSpot_ECM6(i) <= 0
2523         SignPred_ECM6.True1(i) = 1;
2524     else
2525         SignPred_ECM6.True1(i) = 0;
2526     end
2527 end
2528
2529 PercentCorrect_ECM6 = (sum(SignPred_ECM6.True) + sum(SignPred_ECM6.True1)
        ) / (height(Predictions_ECM6));
2530
2531
2532
2533 % ECM-GARCH: Spot and Fut14:
2534 GARCH6 = garch('GARCHlags', 1, 'ARCHlags', 1)

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2535 [estMdl, estParamCov, logL] = estimate(GARCH6, ECM6.Spot_firstdiff)
2536 condVar_6 = infer(estMdl, ECM6.Spot_firstdiff);
2537 ECM6.condVol = sqrt(condVar_6);
2538
2539 ECM_GARCH6 = fitlm(ECM6, ['Spot_firstdiff ~ LaggedResiduals +
    Fut14_firstdiff_lag1 + Fut14_firstdiff_lag2' ...
2540     '+ Fut14_firstdiff_lag3 + Fut14_firstdiff_lag4 + Fut14_firstdiff_lag5
        + Fut14_firstdiff_lag6' ...
2541     '+ Fut14_firstdiff_lag7 + Spot_firstdiff_lag1 + Spot_firstdiff_lag2 +
        Spot_firstdiff_lag3' ...
2542     '+ Spot_firstdiff_lag4 + Spot_firstdiff_lag5 + Spot_firstdiff_lag6 +
        Spot_firstdiff_lag7' ...
2543     '+ condVol'])
2544
2545 Pred14 = forecast(estMdl, height(residuals_6), 'Y0', ECM6.Spot_firstdiff)
    ;
2546 Pred14_Vol = sqrt(Pred14);
2547
2548
2549 Predicted_SpotFD_GARCH6 = [ECM_GARCH6.Coefficients.Estimate(1) +
    ECM_GARCH6.Coefficients.Estimate(3)*data.Fut14_firstdiff_lag1
    (247:493) ...
2550     + ECM_GARCH6.Coefficients.Estimate(4)*data.Fut14_firstdiff_lag2
    (247:493) + ECM_GARCH6.Coefficients.Estimate(5)*data.
    Fut14_firstdiff_lag3(247:493) ...
2551     + ECM_GARCH6.Coefficients.Estimate(6)*data.Fut14_firstdiff_lag4
    (247:493) + ECM_GARCH6.Coefficients.Estimate(7)*data.
    Fut14_firstdiff_lag5(247:493) ...
2552     + ECM_GARCH6.Coefficients.Estimate(8)*data.Fut14_firstdiff_lag6
    (247:493) + ECM_GARCH6.Coefficients.Estimate(9)*data.
    Fut14_firstdiff_lag7(247:493) ...
2553     + ECM_GARCH6.Coefficients.Estimate(10)*data.Spot_firstdiff_lag1
    (247:493) + ECM_GARCH6.Coefficients.Estimate(11)*data.
    Spot_firstdiff_lag2(247:493) ...
2554     + ECM_GARCH6.Coefficients.Estimate(12)*data.Spot_firstdiff_lag3
    (247:493) + ECM_GARCH6.Coefficients.Estimate(13)*data.
    Spot_firstdiff_lag4(247:493) ...
2555     + ECM_GARCH6.Coefficients.Estimate(14)*data.Spot_firstdiff_lag5
    (247:493) + ECM_GARCH6.Coefficients.Estimate(15)*data.
    Spot_firstdiff_lag6(247:493) ...
2556     + ECM_GARCH6.Coefficients.Estimate(16)*data.Spot_firstdiff_lag7
    (247:493) + ECM_GARCH6.Coefficients.Estimate(17)*Pred14_Vol ...
2557     + ECM_GARCH6.Coefficients.Estimate(2)*residuals_6.LaggedResiduals];
2558
2559 Predictions_GARCH6 = table();
2560 Predictions_GARCH6.Date = data.Date(246:493);
2561 Predictions_GARCH6.Spot = data.Spot(246:493);
2562 Predictions_GARCH6.PredictedSpotFD = zeros(248,1);
2563 Predictions_GARCH6.PredictedSpotFD(2:end) = Predicted_SpotFD_GARCH6;
2564 Predictions_GARCH6.PredictedSpot = lagmatrix(Predictions_GARCH6.Spot, 1)
    + Predictions_GARCH6.PredictedSpotFD;
2565 Predictions_GARCH6(1,:) = [];
2566 Predictions_GARCH6.Spot = exp(Predictions_GARCH6.Spot);
2567 Predictions_GARCH6.PredictedSpot = exp(Predictions_GARCH6.PredictedSpot);
2568 Predictions_GARCH6(241:end,:) = [];
2569
2570 MSE_GARCH6 = (sum(Predictions_GARCH6.PredictedSpot - Predictions_GARCH6.
    Spot)^2)/(240);
2571 RMSE_GARCH6 = sqrt(MSE_GARCH6)
2572
2573 ChangePred_GARCH6 = Predictions_GARCH6.PredictedSpot - lagmatrix(

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        Predictions_GARCH6.PredictedSpot, 1);
2574 ChangeSpot_GARCH6 = Predictions_GARCH6.Spot - lagmatrix(
        Predictions_GARCH6.Spot, 1);
2575
2576 SignPred_GARCH6 = table();
2577 for i = 1:height(Predictions_GARCH6)
2578     if ChangePred_GARCH6(i) >= 0 & ChangeSpot_GARCH6(i) >= 0
2579         SignPred_GARCH6.True(i) = 1;
2580     else
2581         SignPred_GARCH6.True(i) = 0;
2582     end
2583 end
2584
2585 for i = 1:height(Predictions_GARCH6)
2586     if ChangePred_GARCH6(i) <= 0 & ChangeSpot_GARCH6(i) <= 0
2587         SignPred_GARCH6.True1(i) = 1;
2588     else
2589         SignPred_GARCH6.True1(i) = 0;
2590     end
2591 end
2592 PercentCorrect_GARCH6 = (sum(SignPred_GARCH6.True) + sum(SignPred_GARCH6.
        True1)) / (height(Predictions_GARCH6));
2593
2594 % Plots of all models:
2595 figure;
2596 subplot(2,2,1)
2597 plot(Predictions_ECM1.Date, Predictions_ECM1.Spot)
2598 hold on
2599 plot(Predictions_ECM1.Date, Predictions_ECM1.PredictedSpot)
2600 legend('Actual spot', 'Predicted spot', 'Location', 'NorthEast')
2601 title('Predictions by ECM with Dec19 Futures contract')
2602 xlabel('Year')
2603 ylabel('Price in EUR')
2604 box('off')
2605 hold off
2606
2607 subplot(2,2,2)
2608 plot(Predictions_GARCH1.Date, Predictions_GARCH1.Spot)
2609 hold on
2610 plot(Predictions_GARCH1.Date, Predictions_GARCH1.PredictedSpot)
2611 legend('Actual spot', 'Predicted spot', 'Location', 'NorthEast')
2612 title('Predictions by ECM-GARCH with Dec19 Futures contract')
2613 xlabel('Year')
2614 ylabel('Price in EUR')
2615 box('off')
2616 hold off
2617
2618 subplot(2,2,3)
2619 plot(Predictions_ECM2.Date, Predictions_ECM2.Spot)
2620 hold on
2621 plot(Predictions_ECM2.Date, Predictions_ECM2.PredictedSpot)
2622 legend('Actual spot', 'Predicted spot', 'Location', 'NorthEast')
2623 title('Predictions by ECM with Dec18 Futures contract')
2624 xlabel('Year')
2625 ylabel('Price in EUR')
2626 box('off')
2627 hold off
2628
2629 subplot(2,2,4)
2630 plot(Predictions_GARCH2.Date, Predictions_GARCH2.Spot)
2631 hold on

```

```

2632 plot(Predictions_GARCH2.Date, Predictions_GARCH2.PredictedSpot)
2633 legend('Actual spot', 'Predicted spot', 'Location', 'NorthEast')
2634 title('Predictions by ECM-GARCH with Dec18 Futures contract')
2635 xlabel('Year')
2636 ylabel('Price in EUR')
2637 box('off')
2638 hold off
2639
2640 figure;
2641 subplot(2,2,1)
2642 plot(Predictions_ECM3.Date, Predictions_ECM3.Spot)
2643 hold on
2644 plot(Predictions_ECM3.Date, Predictions_ECM3.PredictedSpot)
2645 legend('Actual spot', 'Predicted spot', 'Location', 'SouthEast')
2646 title('Predictions by ECM with Dec17 Futures contract')
2647 xlabel('Year')
2648 ylabel('Price in EUR')
2649 box('off')
2650 hold off
2651
2652 subplot(2,2,2)
2653 plot(Predictions_GARCH3.Date, Predictions_GARCH3.Spot)
2654 hold on
2655 plot(Predictions_GARCH3.Date, Predictions_GARCH3.PredictedSpot)
2656 legend('Actual spot', 'Predicted spot', 'Location', 'SouthEast')
2657 title('Predictions by ECM-GARCH with Dec17 Futures contract')
2658 xlabel('Year')
2659 ylabel('Price in EUR')
2660 box('off')
2661 hold off
2662
2663 subplot(2,2,3)
2664 plot(Predictions_ECM4.Date, Predictions_ECM4.Spot)
2665 hold on
2666 plot(Predictions_ECM4.Date, Predictions_ECM4.PredictedSpot)
2667 legend('Actual spot', 'Predicted spot', 'Location', 'NorthEast')
2668 title('Predictions by ECM with Dec16 Futures contract')
2669 xlabel('Year')
2670 ylabel('Price in EUR')
2671 box('off')
2672 hold off
2673
2674 subplot(2,2,4)
2675 plot(Predictions_GARCH4.Date, Predictions_GARCH4.Spot)
2676 hold on
2677 plot(Predictions_GARCH4.Date, Predictions_GARCH4.PredictedSpot)
2678 legend('Actual spot', 'Predicted spot', 'Location', 'NorthEast')
2679 title('Predictions by ECM-GARCH with Dec16 Futures contract')
2680 xlabel('Year')
2681 ylabel('Price in EUR')
2682 box('off')
2683 hold off
2684
2685 figure;
2686 subplot(2,2,1)
2687 plot(Predictions_ECM5.Date, Predictions_ECM5.Spot)
2688 hold on
2689 plot(Predictions_ECM5.Date, Predictions_ECM5.PredictedSpot)
2690 legend('Actual spot', 'Predicted spot', 'Location', 'SouthEast')
2691 title('Predictions by ECM with Dec15 Futures contract')
2692 xlabel('Year')

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2693 ylabel('Price in EUR')
2694 box('off')
2695 hold off
2696
2697 subplot(2,2,2)
2698 plot(Predictions_GARCH5.Date, Predictions_GARCH5.Spot)
2699 hold on
2700 plot(Predictions_GARCH5.Date, Predictions_GARCH5.PredictedSpot)
2701 legend('Actual spot', 'Predicted spot', 'Location', 'SouthEast')
2702 title('Predictions by ECM-GARCH with Dec15 Futures contract')
2703 xlabel('Year')
2704 ylabel('Price in EUR')
2705 box('off')
2706 hold off
2707
2708 subplot(2,2,3)
2709 plot(Predictions_ECM6.Date, Predictions_ECM6.Spot)
2710 hold on
2711 plot(Predictions_ECM6.Date, Predictions_ECM6.PredictedSpot)
2712 legend('Actual spot', 'Predicted spot', 'Location', 'SouthEast')
2713 title('Predictions by ECM with Dec14 Futures contract')
2714 xlabel('Year')
2715 ylabel('Price in EUR')
2716 box('off')
2717 hold off
2718
2719 subplot(2,2,4)
2720 plot(Predictions_GARCH6.Date, Predictions_GARCH6.Spot)
2721 hold on
2722 plot(Predictions_GARCH6.Date, Predictions_GARCH6.PredictedSpot)
2723 legend('Actual spot', 'Predicted spot', 'Location', 'SouthEast')
2724 title('Predictions by ECM-GARCH with Dec14 Futures contract')
2725 xlabel('Year')
2726 ylabel('Price in EUR')
2727 box('off')
2728 hold off
2729
2730 %% Part 6 – Link to fundamental variables:
2731 clear;
2732 clc;
2733
2734 % Import data and create variables:
2735 data = readtable('Spot+DecFutures.xlsx');
2736 data=data(~any(ismissing(data.Spot),2),:);
2737 data(584:585,:) = [];
2738 data = table2timetable(data);
2739 data.Spot = log(data.Spot);
2740 data.Oil = log(data.Oil);
2741 data.Electricity = log(data.Electricity);
2742 data.Elec = data.Electricity;
2743 data.Coal = log(data.Coal);
2744 data.DAX = log(data.DAX);
2745 data.NaturalGAS = log(data.NaturalGAS);
2746 data.Ngas = data.NaturalGAS;
2747 data(1:556,:) = [];
2748
2749
2750 % First differences:
2751 data.Spot_fd = data.Spot - lagmatrix(data.Spot,1);
2752 data.Oil_fd = data.Oil - lagmatrix(data.Oil,1);
2753 data.Elec_fd = data.Elec - lagmatrix(data.Elec,1);

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```

2754 data.Coal_fd = data.Coal - lagmatrix(data.Coal,1);
2755 data.DAX_fd = data.DAX - lagmatrix(data.DAX,1);
2756 data.Ngas_fd = data.Ngas - lagmatrix(data.Ngas,1);
2757
2758
2759 % Determining lag length for VAR (full model):
2760 reg_VAR1 = table();
2761 reg_VAR1.Spot_fd = data.Spot_fd;
2762 reg_VAR1.Oil_fd = data.Oil_fd;
2763 reg_VAR1.Elec_fd = data.Elec_fd;
2764 reg_VAR1.Coal_fd = data.Coal_fd;
2765 reg_VAR1.DAX_fd = data.DAX_fd;
2766 reg_VAR1.Ngas_fd = data.Ngas_fd;
2767 reg_VAR1(1707:end,:) = [];
2768 reg_VAR1=reg_VAR1(~any(ismissing(reg_VAR1.Elec_fd),2),:);
2769 reg_VAR1=reg_VAR1(~any(ismissing(reg_VAR1.DAX_fd),2),:);
2770 reg_VAR1=reg_VAR1(~any(ismissing(reg_VAR1.Ngas_fd),2),:);
2771 reg_VAR1=reg_VAR1(~any(ismissing(reg_VAR1.Coal_fd),2),:);
2772 reg_VAR1 = reg_VAR1{:,:};
2773 [laglength, AIC, logL] = VARlag(reg_VAR1,12)
2774 %Optimal = 2
2775
2776
2777 % Simple regressions:
2778 data1 = table();
2779 data1.Spot_fd = data.Spot_fd;
2780 data1.Oil_fd = data.Oil_fd;
2781 data1.Elec_fd = data.Elec_fd;
2782 data1.Coal_fd = data.Coal_fd;
2783 data1.DAX_fd = data.DAX_fd;
2784 data1.Ngas_fd = data.Ngas_fd;
2785 OLS_1 = fitlm(data1, 'Spot_fd ~ Oil_fd + Elec_fd + Coal_fd + DAX_fd +
    Ngas_fd')
2786
2787
2788 % Spot carbon and oil:
2789 data2 = table();
2790 data2.Spot_fd = data.Spot_fd;
2791 data2.Oil_fd = data.Oil_fd;
2792 OLS_2 = fitlm(data2, 'Spot_fd ~ Oil_fd')
2793
2794
2795 % Spot carbon and elec:
2796 data3 = table();
2797 data3.Spot_fd = data.Spot_fd;
2798 data3.Elec_fd = data.Elec_fd;
2799 OLS_3 = fitlm(data3, 'Spot_fd ~ Elec_fd')
2800
2801 % Spot carbon and Coal:
2802 data4 = table();
2803 data4.Spot_fd = data.Spot_fd;
2804 data4.Coal_fd = data.Coal_fd;
2805 OLS_4 = fitlm(data4, 'Spot_fd ~ Coal_fd')
2806
2807 % Spot carbon and DAX:
2808 data5 = table();
2809 data5.Spot_fd = data.Spot_fd;
2810 data5.DAX_fd = data.DAX_fd;
2811 OLS_5 = fitlm(data5, 'Spot_fd ~ DAX_fd')
2812
2813 % Spot and Ngas:

```



```

2814 data6 = table();
2815 data6.Spot_fd = data.Spot_fd;
2816 data6.Ngas_fd = data.Ngas_fd;
2817 OLS_6 = fitlm(data6, 'Spot_fd ~ Ngas_fd')
2818
2819 % Second analysis – Full VAR with impulse responses:
2820 table1 = data(:, {'Spot_fd', 'Oil_fd', 'Elec_fd', 'Coal_fd', 'DAX_fd', '
      Ngas_fd'});
2821 k = 2;
2822 g = size(table1,2);
2823 model = estimate( varm( g , k ), table1.Variables );
2824 results = summarize(model);
2825
2826 % Extracting summary statistics to excel:
2827 writetable(results.Table, 'VARtest2.xlsx', 'Sheet', 1, 'Range', 'B1');
2828
2829 T = 20;
2830 Y = armaurf(model.AR, [], 'NumObs', T);
2831
2832 % plot
2833 figure('WindowStyle', 'docked');
2834 subplot(2,3,1); plot((1:T)', Y(:,1,1), 'LineWidth', 1); title('Response
      of Spot to Spot'); grid('on');
2835 subplot(2,3,2); plot((1:T)', Y(:,1,2), 'LineWidth', 1); ylim([-0.06,
      0.06]); title('Response of Spot to Oil'); grid('on');
2836 subplot(2,3,3); plot((1:T)', Y(:,1,3), 'LineWidth', 1); ylim([-0.01,
      0.01]); title('Response of Spot to Elec'); grid('on');
2837 subplot(2,3,4); plot((1:T)', Y(:,1,4), 'LineWidth', 1); title('Response
      of Spot to Coal'); grid('on');
2838 subplot(2,3,5); plot((1:T)', Y(:,1,5), 'LineWidth', 1); ylim([-0.03,
      0.07]); title('Response of Spot to DAX'); grid('on');
2839 subplot(2,3,6); plot((1:T)', Y(:,1,6), 'LineWidth', 1); ylim([-0.02,
      0.01]); title('Response of Spot to Ngas'); grid('on');
2840 %%

```