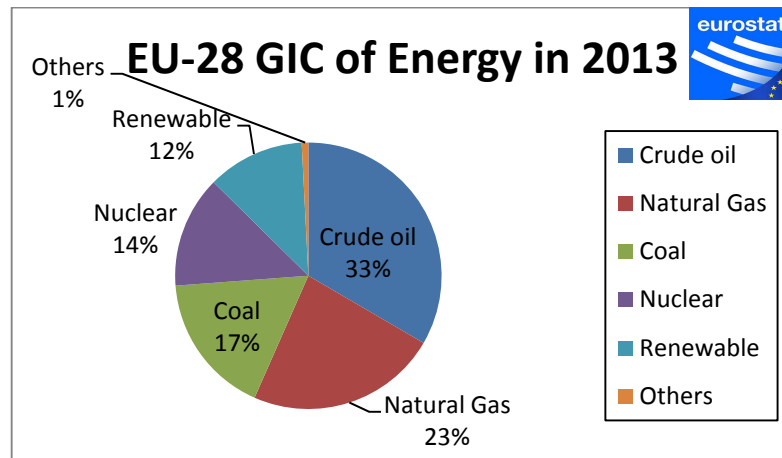
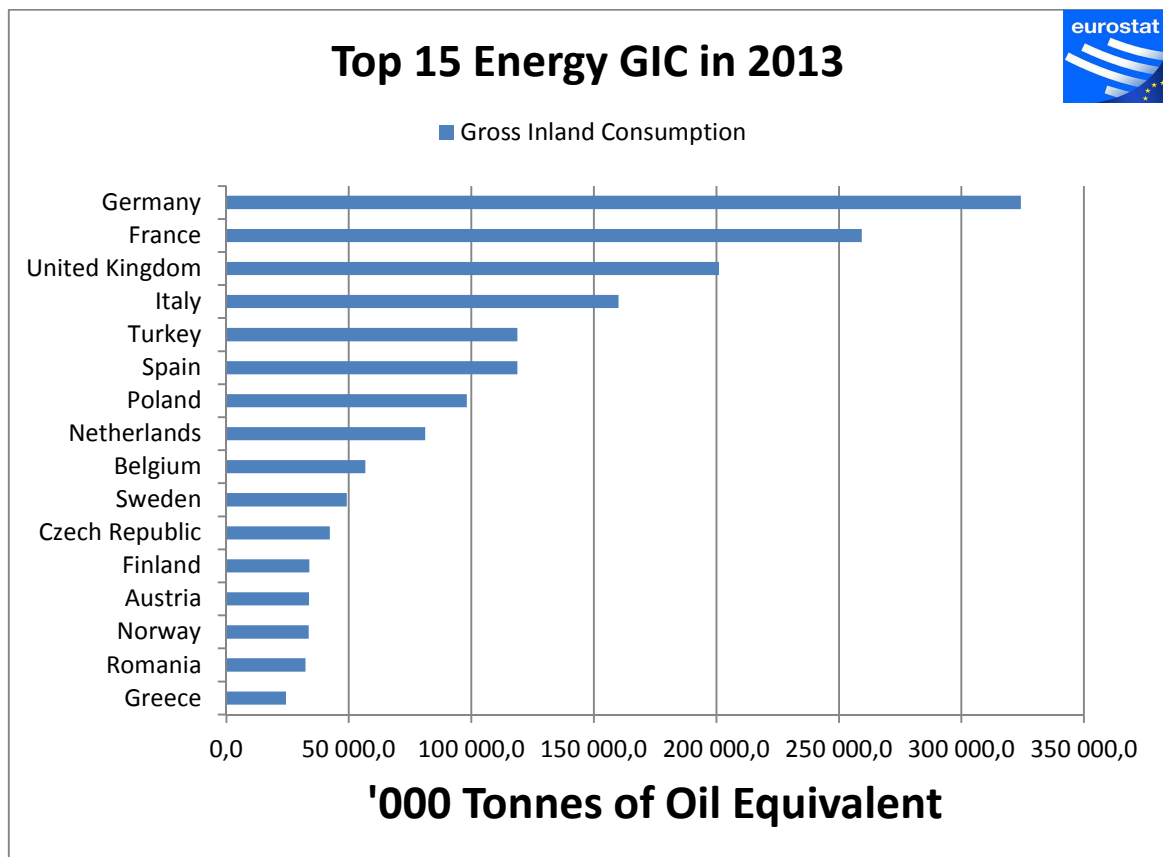


## VI. Appendices

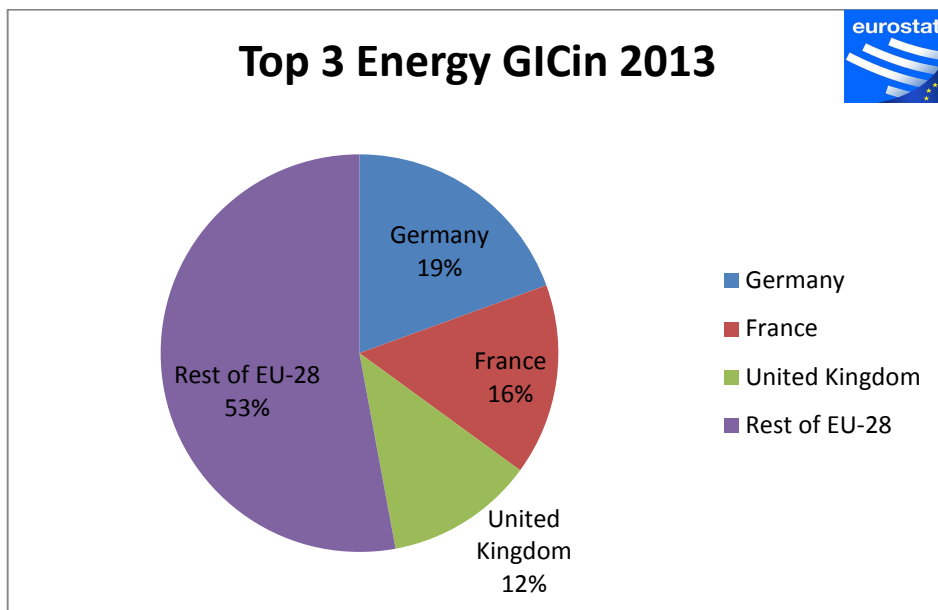
### Appendix 1: EU-28 GIC in 2013.



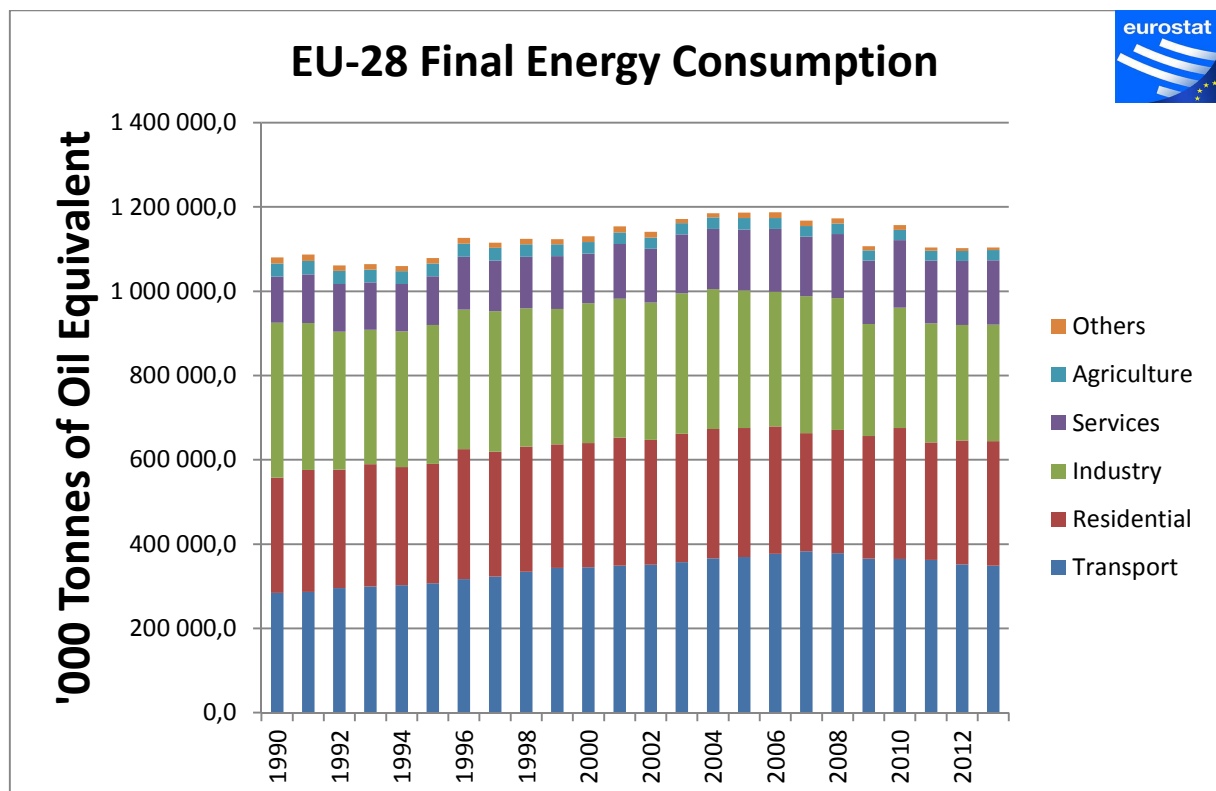
### Appendix 2: 15 biggest EU-28 GIC in 2013 (all products).



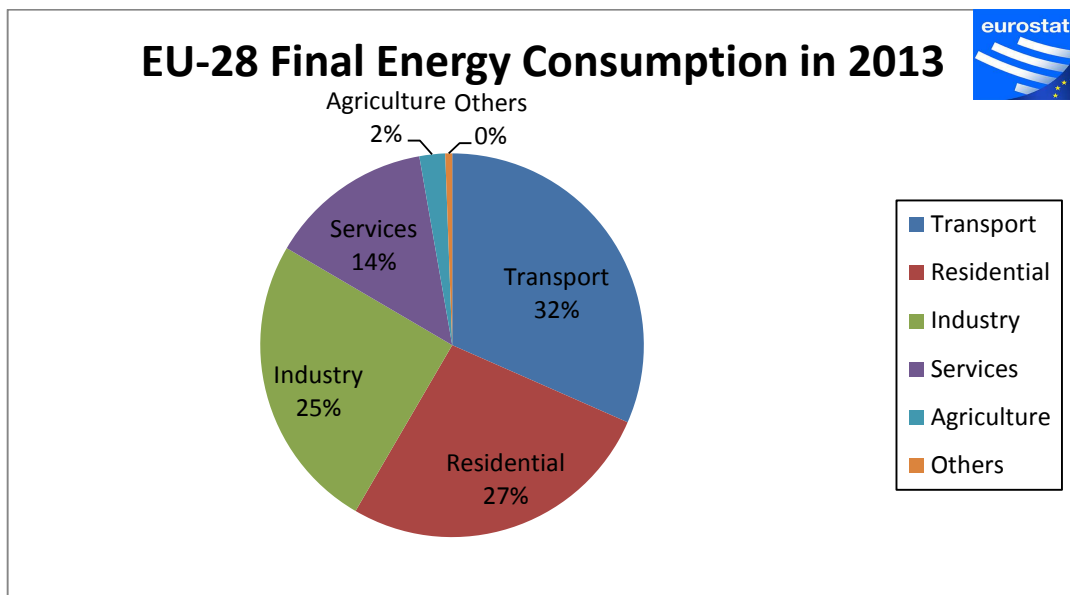
Appendix 3: 3 biggest EU-28 in 2013 (all products).



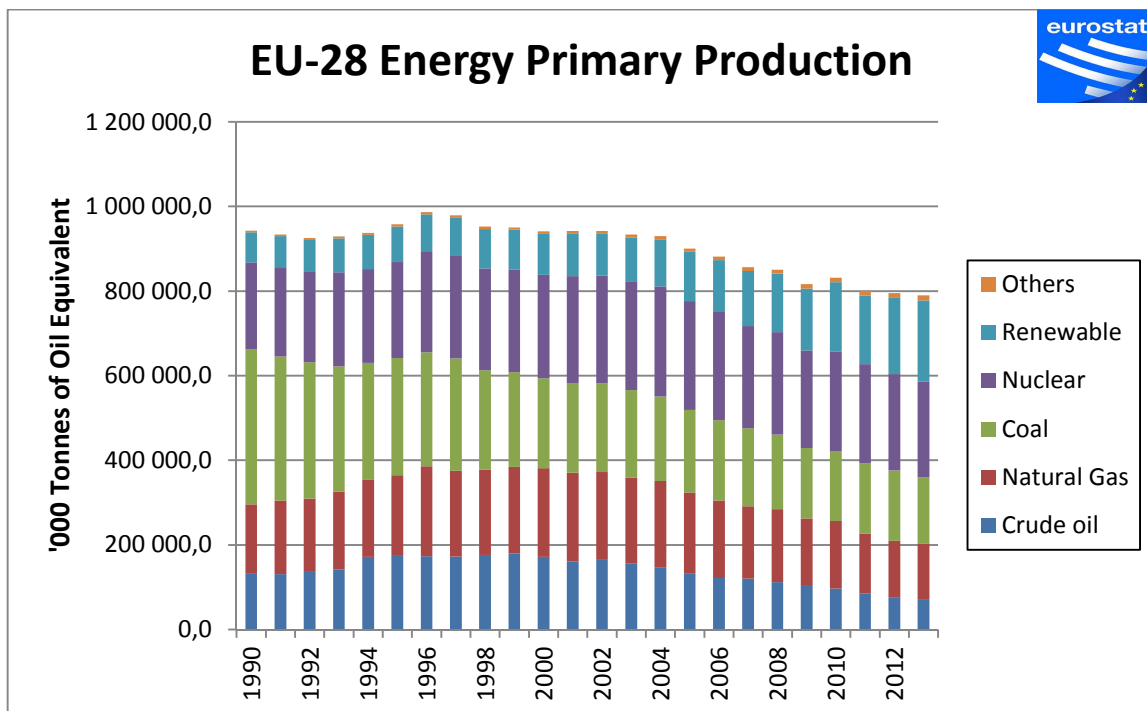
Appendix 4: Evolution of the cumulative EU-28 final energy consumption by sector between 1990 and 2013 (all products).



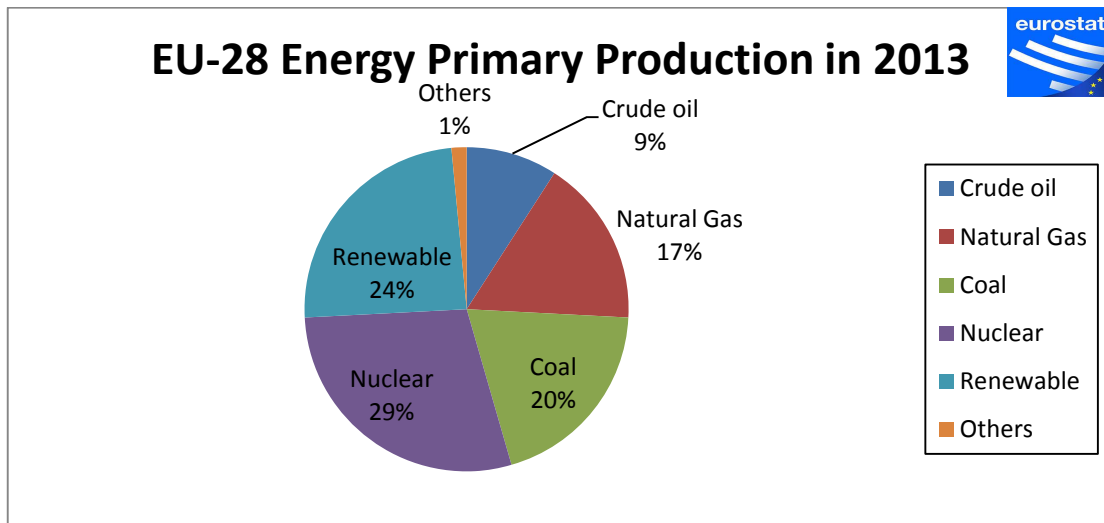
Appendix 5: EU-28 final energy consumption by sector in 2013 (all products).



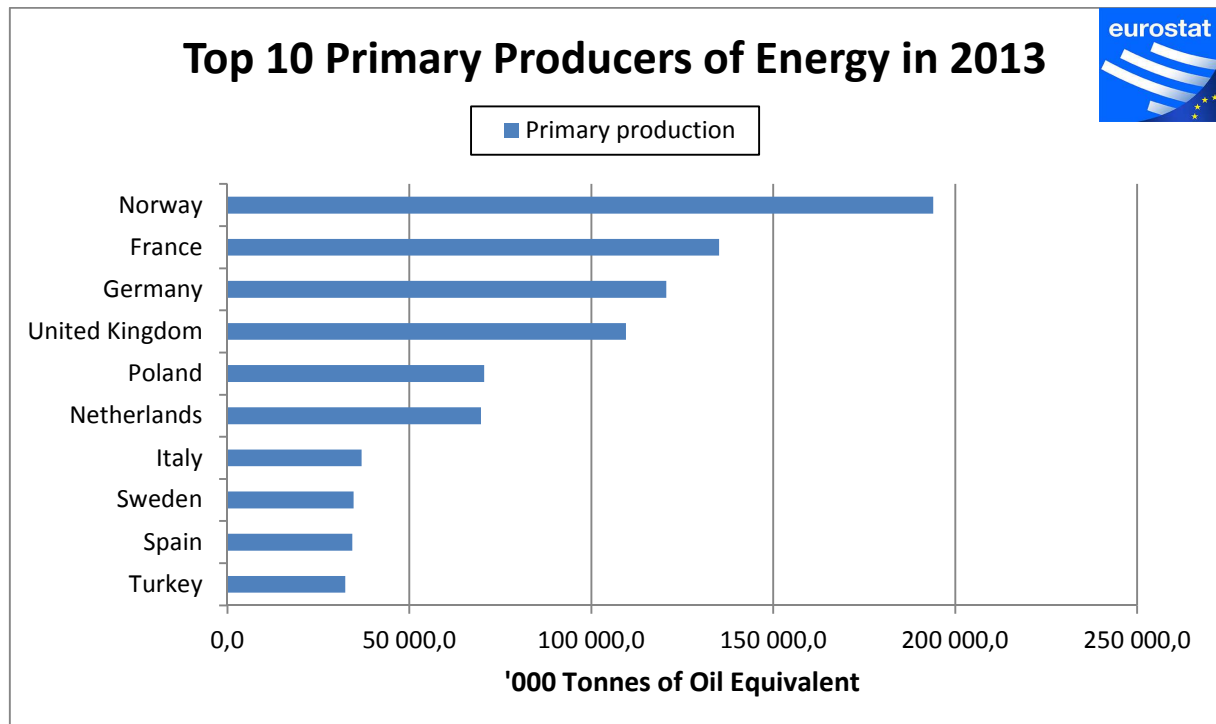
Appendix 6: Evolution of the cumulative EU-28 energy primary production between 1990 and 2013 (all products).



Appendix 7: EU-28 energy primary production in 2013.



Appendix 8: 10 biggest EU-28 primary producers of energy in 2013 (all products).

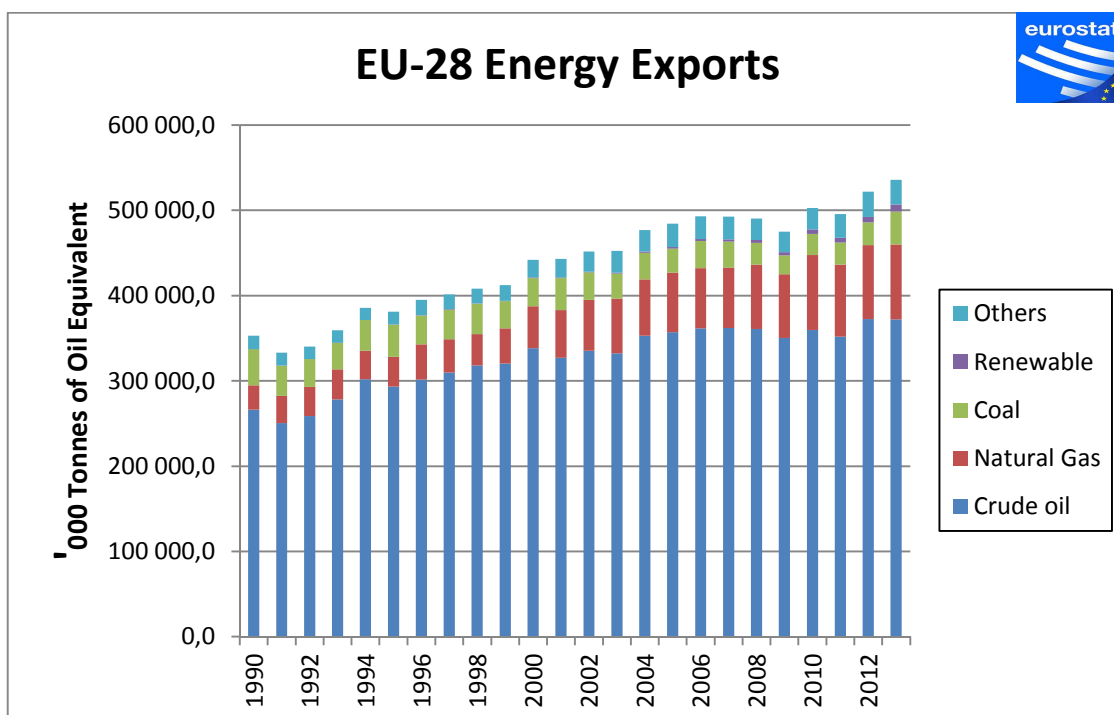


## Appendix 9: EU-28 % origin of primary energy imports.

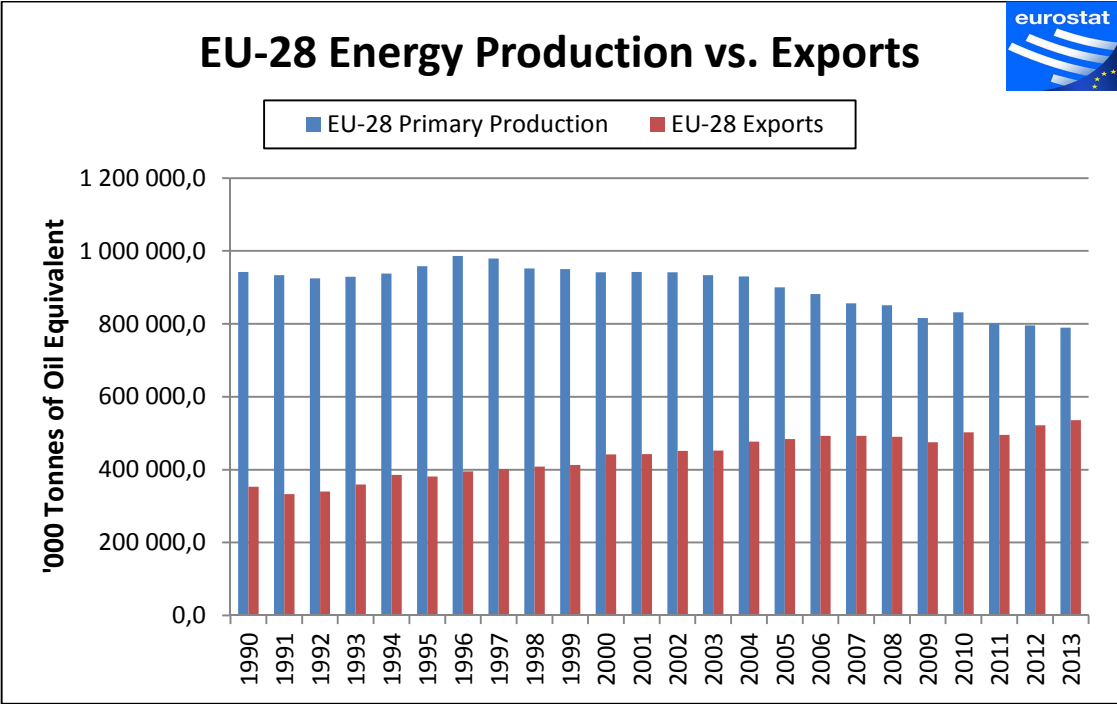
Solid fuels											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Russia	13.1	13.3	18.2	23.7	24.8	24.8	26.1	30.0	26.9	26.2	25.9
Colombia	12.1	11.8	12.1	11.7	11.5	12.7	12.3	17.4	19.9	23.6	23.7
United States	8.1	6.7	7.3	7.6	7.8	9.1	14.0	13.5	16.8	17.8	23.0
Australia	16.1	16.1	14.6	13.1	11.9	13.0	11.7	7.5	10.5	8.7	7.4
South Africa	30.1	29.9	25.4	25.0	23.2	20.1	16.5	15.8	9.6	7.7	6.3
Indonesia	6.6	7.0	6.7	7.2	9.3	7.8	7.3	7.0	5.5	5.0	4.6
Canada	3.1	2.7	2.4	3.2	2.7	3.0	2.6	1.4	2.0	2.2	1.7
Ukraine	2.3	2.0	2.3	2.2	1.6	1.8	2.3	1.7	1.9	2.3	1.4
Venezuela	1.8	2.6	1.1	1.0	0.8	1.0	1.0	0.7	0.4	0.5	0.5
Others	6.7	7.9	10.1	5.2	6.3	6.7	6.2	5.0	6.4	6.0	5.5
Crude oil											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Russia	29.5	31.2	32.5	32.9	33.8	33.7	31.8	33.5	34.7	34.8	33.7
Norway	19.3	19.1	18.7	16.8	15.4	14.9	15.0	15.1	13.7	12.5	11.1
Saudi Arabia	10.1	11.2	11.3	10.5	9.0	7.2	6.8	5.7	5.9	8.0	8.8
Nigeria	3.5	4.2	2.6	3.2	3.6	2.7	4.0	4.5	4.1	6.1	8.2
Libya	7.4	8.4	8.8	8.7	9.1	9.7	9.9	8.9	10.1	2.8	8.2
Kazakhstan	2.4	2.7	3.3	4.4	4.6	4.6	4.8	5.3	5.5	5.7	5.1
Iraq	3.0	1.5	2.2	2.1	2.9	3.4	3.3	3.8	3.2	3.6	4.1
Azerbaijan	1.0	1.0	0.9	1.3	2.2	3.0	3.2	4.0	4.4	4.9	3.9
Algeria	2.7	3.0	3.3	3.5	2.5	1.9	2.5	1.6	1.2	2.6	2.9
Others	21.1	17.7	16.4	16.5	16.8	18.9	18.7	17.6	17.1	19.1	14.0
Natural gas											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Russia	45.2	44.1	43.6	40.7	39.3	38.7	37.6	33.0	29.5	31.6	32.0
Norway	26.1	25.5	24.3	23.8	25.9	28.1	28.4	29.4	27.5	27.4	31.3
Algeria	21.1	19.8	18.0	17.6	16.3	15.3	14.7	14.2	14.0	13.0	13.5
Qatar	0.9	0.7	1.4	1.5	1.8	2.2	2.3	5.5	9.7	11.0	8.4
Nigeria	2.2	3.1	3.6	3.4	4.3	4.6	4.0	2.4	4.1	4.3	3.6
Libya	0.3	0.3	0.4	1.6	2.5	3.0	2.9	2.9	2.7	0.7	1.9
Trinidad and Tobago	0.2	0.0	0.0	0.2	1.2	0.8	1.7	2.2	1.4	1.0	0.9
Peru	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Egypt	0.0	0.0	0.0	1.6	2.5	1.7	1.7	2.1	1.3	1.2	0.6
Others	4.1	6.5	8.6	9.5	6.3	5.5	6.6	8.2	9.7	9.8	7.1

Source: Eurostat (online data codes: nrg\_122a, nrg\_123a and nrg\_124a)

## Appendix 10: Evolution of the cumulative EU-28 energy exports between 1990 and 2013.



Appendix 11: Comparative of the EU-28 energy primary production and exports between 1990 and 2013.



Appendix 12: Critical values of Engle and Yoo (1987) for the DF cointegration test ( $p=0$ ).

Number of var's $N$	Sample size $T$	Significance level		
		1%	5%	10%
1 <sup>a</sup>	50	2.62	1.95	1.61
	100	2.60	1.95	1.61
	250	2.58	1.95	1.62
	500	2.58	1.95	1.62
	$\infty$	2.58	1.95	1.62
1 <sup>b</sup>	50	3.58	2.93	2.60
	100	3.51	2.89	2.58
	250	3.46	2.88	2.57
	500	3.44	2.87	2.57
	$\infty$	3.43	2.86	2.57
2	50	4.32	3.67	3.28
	100	4.07	3.37	3.03
	200	4.00	3.37	3.02
3	50	4.84	4.11	3.73
	100	4.45	3.93	3.59
	200	4.35	3.78	3.47
4	50	4.94	4.35	4.02
	100	4.75	4.22	3.89
	200	4.70	4.18	3.89
5	50	5.41	4.76	4.42
	100	5.18	4.58	4.26
	200	5.02	4.48	4.18

<sup>a</sup>Critical values of  $\hat{r}$ .  
<sup>b</sup>Critical values of  $\hat{r}_\mu$ . Both cited from Fuller (1976, p. 373).

Appendix 13: Critical values of Engle and Yoo (1987) for the DF cointegration test ( $p=4$ ).

Number of var's $N$	Sample size $T$	Significance level		
		1%	5%	10%
2	50	4.12	3.29	2.90
	100	3.73	3.17	2.91
	200	3.78	3.25	2.98
3	50	4.45	3.75	3.36
	100	4.22	3.62	3.32
	200	4.34	3.78	3.51
4	50	4.61	3.98	3.67
	100	4.61	4.02	3.71
	200	4.72	4.13	3.83
5	50	4.80	4.15	3.85
	100	4.98	4.36	4.06
	200	4.97	4.43	4.14

Appendix 14: Critical values of McKinnon (1991) for the ADF cointegration test without trend.

$N$	Variant	Level	Obs.	$\beta_{\infty}$	(s.e.)	$\beta_1$	$\beta_2$	$\beta_3$
1	$\tau_{nc}$	1%	15,000	-2.56574	(0.000110)	-2.2358	-3.627	
1	$\tau_{nc}$	5%	15,000	-1.94100	(0.000074)	-0.2686	-3.365	31.223
1	$\tau_{nc}$	10%	15,000	-1.61682	(0.000059)	0.2656	-2.714	25.364
1	$\tau_c$	1%	15,000	-3.43035	(0.000127)	-6.5393	-16.786	-79.433
1	$\tau_c$	5%	15,000	-2.86154	(0.000068)	-2.8903	-4.234	-40.040
1	$\tau_c$	10%	15,000	-2.56677	(0.000043)	-1.5384	-2.809	
2	$\tau_c$	1%	15,000	-3.89644	(0.000102)	-10.9519	-22.527	
2	$\tau_c$	5%	15,000	-3.33613	(0.000056)	-6.1101	-6.823	
2	$\tau_c$	10%	15,000	-3.04445	(0.000044)	-4.2412	-2.720	
3	$\tau_c$	1%	15,000	-4.29374	(0.000123)	-14.4354	-33.195	47.433
3	$\tau_c$	5%	15,000	-3.74066	(0.000067)	-8.5631	-10.852	27.982
3	$\tau_c$	10%	15,000	-3.45218	(0.000043)	-6.2143	-3.718	
4	$\tau_c$	1%	15,000	-4.64332	(0.000101)	-18.1031	-37.972	
4	$\tau_c$	5%	15,000	-4.09600	(0.000055)	-11.2349	-11.175	
4	$\tau_c$	10%	15,000	-3.81020	(0.000043)	-8.3931	-4.137	
5	$\tau_c$	1%	15,000	-4.95756	(0.000101)	-21.8883	-45.142	
5	$\tau_c$	5%	15,000	-4.41519	(0.000055)	-14.0406	-12.575	
5	$\tau_c$	10%	15,000	-4.13157	(0.000043)	-10.7417	-3.784	
6	$\tau_c$	1%	15,000	-5.24568	(0.000124)	-25.6688	-57.737	88.639
6	$\tau_c$	5%	15,000	-4.70693	(0.000068)	-16.9178	-17.492	60.007
6	$\tau_c$	10%	15,000	-4.42501	(0.000054)	-13.1875	-5.104	27.877

## Appendix 15: Critical values of McKinnon (1991) for the ADF cointegration test with trend.

**Table 3. Critical Values for Linear Trend Case ( $\tau_{ct}$ )**

$N$	Level	Obs.	$\beta_{0c}$	(s.e.)	$\beta_1$	$\beta_2$	$\beta_3$
1	1%	15,000	-3.95877	(0.000122)	-9.0531	-28.428	-134.155
1	5%	15,000	-3.41049	(0.000066)	-4.3904	-9.036	-45.374
1	10%	15,000	-3.12705	(0.000051)	-2.5856	-3.925	-22.380
2	1%	15,000	-4.32762	(0.000099)	-15.4387	-35.679	
2	5%	15,000	-3.78057	(0.000054)	-9.5106	-12.074	
2	10%	15,000	-3.49631	(0.000053)	-7.0815	-7.538	21.892
3	1%	15,000	-4.66305	(0.000126)	-18.7688	-49.793	104.244
3	5%	15,000	-4.11890	(0.000066)	-11.8922	-19.031	77.332
3	10%	15,000	-3.83511	(0.000053)	-9.0723	-8.504	35.403
4	1%	15,000	-4.96940	(0.000125)	-22.4694	-52.599	51.314
4	5%	15,000	-4.42871	(0.000067)	-14.5876	-18.228	39.647
4	10%	15,000	-4.14633	(0.000054)	-11.2500	-9.873	54.109
5	1%	15,000	-5.25276	(0.000123)	-26.2183	-59.631	50.646
5	5%	15,000	-4.71537	(0.000068)	-17.3569	-22.660	91.359
5	10%	15,000	-4.43422	(0.000054)	-13.6078	-10.238	76.781
6	1%	15,000	-5.51727	(0.000125)	-29.9760	-75.222	202.253
6	5%	15,000	-4.98228	(0.000066)	-20.3050	-25.224	132.030
6	10%	15,000	-4.70233	(0.000053)	-16.1253	-9.836	94.272

## Appendix 16: Critical values of Osterwald-Lenum (1992).

$n - r$	Case I			Case II			Case III		
	90%	95%	99%	90%	95%	99%	90%	95%	99%
Maximum eigenvalue test									
1	2.86	3.84	6.51	2.69	3.76	6.65	7.52	9.24	12.97
2	9.52	11.44	15.69	12.07	14.07	18.63	13.75	15.67	20.20
3	15.59	17.89	22.99	18.60	20.97	25.52	19.77	22.00	26.81
4	21.58	23.80	28.82	24.73	27.07	32.24	25.56	28.14	33.24
5	27.62	30.04	35.17	30.90	33.46	38.77	31.66	34.40	39.79
6	33.62	36.36	41.00	36.76	39.37	45.10	37.45	40.30	46.82
7	38.98	41.51	47.15	42.32	45.28	51.57	43.25	46.45	51.91
8	44.99	47.99	53.90	48.33	51.42	57.69	48.91	52.00	57.95
9	50.65	53.69	59.78	53.98	57.12	62.80	54.35	57.42	63.71
10	56.09	59.06	65.21	59.62	62.81	69.09	60.25	63.57	69.94
11	61.96	65.30	72.36	65.38	68.83	75.95	66.02	69.74	76.63
Trace test									
1	2.86	3.84	6.51	2.69	3.76	6.65	7.52	9.24	12.97
2	10.47	12.53	16.31	13.33	15.41	20.04	17.85	19.96	24.60
3	21.63	24.31	29.75	26.79	29.68	35.65	32.00	34.91	41.07
4	36.58	39.89	45.58	43.95	47.21	54.46	49.65	53.12	60.16
5	55.44	59.46	66.52	64.84	68.52	76.07	71.86	76.07	84.45
6	78.36	82.49	90.45	89.48	94.15	103.18	97.18	102.14	111.01
7	104.77	109.99	119.80	118.50	124.24	133.57	126.58	131.70	143.09
8	135.24	141.20	152.32	150.53	156.00	168.36	159.48	165.58	177.20
9	169.45	175.77	187.31	186.39	192.89	204.95	196.37	202.92	215.74
10	206.05	212.67	226.40	225.85	233.13	247.18	236.54	244.15	257.68
11	248.45	255.27	269.81	269.96	277.71	293.44	282.45	291.40	307.64

Source: Osterwald-Lenum (1992).

Appendix 17: Shapiro normality test R code.

```

> shapiro.test(lnoil)
      Shapiro-wilk normality test

data:  lnoil
W = 0.9174, p-value = 2.098e-14

> shapiro.test(lngas)
      Shapiro-wilk normality test

data:  lngas
W = 0.90158, p-value = 7.763e-16

> shapiro.test(lncoal)
      Shapiro-wilk normality test

data:  lncoal
W = 0.90291, p-value = 1.009e-15

```

Appendix 18: ADF unit root test R code.

```

> lnoil.adf=ur.df(lnoil,type='trend',selectlags="AIC")
> summary(lnoil.adf)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression trend

Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:
    Min       1Q   Median       3Q      Max
-0.26913 -0.04537  0.00639  0.04342  0.42042

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.103e-02  2.180e-02   2.341  0.01970 *
z.lag.1     -2.002e-02  7.600e-03  -2.634  0.00875 **
tt           9.163e-05  4.241e-05   2.160  0.03131 *
z.diff.lag   3.067e-01  4.703e-02   6.522  2.03e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07749 on 414 degrees of freedom
Multiple R-squared:  0.1051, Adjusted R-squared:  0.09859
F-statistic: 16.2 on 3 and 414 DF, p-value: 5.626e-10

Value of test-statistic is: -2.6342 2.4201 3.6105

Critical values for test statistics:
      1pct  5pct 10pct
tau3  -3.98 -3.42 -3.13
phi2   6.15  4.71  4.05
phi3   8.34  6.30  5.36

```

```

> lngas.adf=ur.df(lngas,type='trend',selectlags="AIC")
> summary(lngas.adf)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression trend

Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:
    Min       1Q   Median       3Q      Max
-0.33955 -0.01013  0.00008  0.00918  0.29567

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  4.500e-03  6.558e-03   0.686  0.4930
z.lag.1      -9.754e-03  5.659e-03  -1.724  0.0855 .
tt           5.493e-05  2.601e-05   2.112  0.0353 *
z.diff.lag   1.132e-01  4.892e-02   2.313  0.0212 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04757 on 414 degrees of freedom
Multiple R-squared:  0.02382,    Adjusted R-squared:  0.01675
F-statistic: 3.367 on 3 and 414 DF,  p-value: 0.01863

Value of test-statistic is: -1.7238 1.7479 2.3166

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -3.98 -3.42 -3.13
phi2  6.15  4.71  4.05
phi3  8.34  6.30  5.36

> lncoal.adf=ur.df(lncoal,type='drift',selectlags="AIC")
> summary(lncoal.adf)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression drift

Call:
lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)

Residuals:
    Min       1Q   Median       3Q      Max
-0.26672 -0.01179 -0.00272  0.00914  0.36607

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.040710   0.022875   1.780  0.0759 .
z.lag.1      -0.010443   0.005993  -1.742  0.0822 .

```

```

z.diff.lag  0.292179  0.046954  6.223  1.2e-09  ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.05477 on 415 degrees of freedom
Multiple R-squared:  0.08895,    Adjusted R-squared:  0.08456
F-statistic: 20.26 on 2 and 415 DF,  p-value: 4.029e-09

Value of test-statistic is: -1.7425 1.6062

Critical values for test statistics:
      1pct  5pct 10pct
tau2 -3.44 -2.87 -2.57
phi1  6.47  4.61  3.79

```

### Appendix 19: Phillips-Perron unit root test R code.

```

> lnoil.pp=ur.pp(lnoil,type="Z-tau",model="trend",use.lag=4)
> summary(lnoil.pp)

#####
# Phillips-Perron Unit Root Test #
#####

Test regression with intercept and trend

Call:
lm(formula = y ~ y.l1 + trend)

Residuals:
    Min       1Q   Median       3Q      Max
-0.31630 -0.04169  0.00642  0.04893  0.37517

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 6.289e-02  2.778e-02   2.264  0.0241 *
y.l1        9.822e-01  7.916e-03 124.078 <2e-16 ***
trend       9.614e-05  4.408e-05   2.181  0.0297 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.08119 on 416 degrees of freedom
Multiple R-squared:  0.9856, Adjusted R-squared:  0.9855
F-statistic: 1.424e+04 on 2 and 416 DF,  p-value: < 2.2e-16

Value of test-statistic, type: Z-tau is: -2.5278

      aux. Z statistics
Z-tau-mu      1.1281
Z-tau-beta    2.2569

Critical values for Z statistics:
      1pct      5pct     10pct
critical values -3.984006 -3.422341 -3.133714

> lngas.pp=ur.pp(lngas,type="Z-tau",model="trend",use.lag=4)
> summary(lngas.pp)

```

```
#####
# Phillips-Perron Unit Root Test #
#####

Test regression with intercept and trend

Call:
lm(formula = y ~ y.l1 + trend)

Residuals:
    Min       1Q   Median       3Q      Max
-0.33959 -0.00920  0.00035  0.00914  0.29590

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.545e-02  8.582e-03   1.800  0.0726 .
y.l1        9.908e-01  5.663e-03 174.968 <2e-16 ***
trend       5.570e-05  2.595e-05   2.147  0.0324 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04777 on 416 degrees of freedom
Multiple R-squared:  0.9927, Adjusted R-squared:  0.9926
F-statistic: 2.815e+04 on 2 and 416 DF, p-value: < 2.2e-16

Value of test-statistic, type: Z-tau is: -1.8576

      aux. Z statistics
Z-tau-mu      0.8545
Z-tau-beta    2.0813

Critical values for Z statistics:
           1pct    5pct    10pct
critical values -3.984006 -3.422341 -3.133714

> lncol.pp=ur.pp(lncol,type="Z-tau",model="trend",use.lag=4)
> summary(lngas.pp)

#####
# Phillips-Perron Unit Root Test #
#####

Test regression with intercept and trend

Call:
lm(formula = y ~ y.l1 + trend)

Residuals:
    Min       1Q   Median       3Q      Max
-0.33959 -0.00920  0.00035  0.00914  0.29590

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.545e-02  8.582e-03   1.800  0.0726 .
y.l1        9.908e-01  5.663e-03 174.968 <2e-16 ***
trend       5.570e-05  2.595e-05   2.147  0.0324 *
---

```

```

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04777 on 416 degrees of freedom
Multiple R-squared:  0.9927, Adjusted R-squared:  0.9926
F-statistic: 2.815e+04 on 2 and 416 DF,  p-value: < 2.2e-16

Value of test-statistic, type: Z-tau  is: -1.8576

      aux. Z statistics
Z-tau-mu      0.8545
Z-tau-beta    2.0813

Critical values for Z statistics:
      1pct      5pct      10pct
critical values -3.984006 -3.422341 -3.133714

```

### Appendix 20: Zivot-Andrews unit root test R code.

```

> lnoil.za=ur.za(lnoil,model="both",lag=1)
> summary(lnoil.za)

#####
# Zivot-Andrews Unit Root Test #
#####

Call:
lm(formula = testmat)

Residuals:
    Min       1Q   Median       3Q      Max
-0.25063 -0.04228  0.00624  0.04372  0.37451

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.467e-01  5.679e-02   4.343 1.77e-05 ***
y.l1         9.281e-01  1.611e-02  57.598 < 2e-16 ***
trend       -2.694e-04  9.589e-05  -2.809 0.005205 **
y.d11       3.241e-01  4.715e-02   6.874 2.32e-11 ***
du          5.404e-02  1.599e-02   3.379 0.000796 ***
dt          8.364e-04  2.603e-04   3.214 0.001414 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07605 on 412 degrees of freedom
(2 observations deleted due to missingness)
Multiple R-squared:  0.9875, Adjusted R-squared:  0.9873
F-statistic: 6504 on 5 and 412 DF,  p-value: < 2.2e-16

Teststatistic: -4.4623
Critical values: 0.01= -5.57 0.05= -5.08 0.1= -4.82

Potential break point at position: 346

> AIC(eval(attributes(lnoil.za)$testreg))
[1] -959.6822
> BIC(eval(attributes(lnoil.za)$testreg))
[1] -931.4338

```

```

>
> lngas.za=ur.za(lngas,model="intercept",lag=3)
> summary(lngas.za)

#####
# Zivot-Andrews Unit Root Test #
#####

Call:
lm(formula = testmat)

Residuals:
    Min       1Q   Median       3Q      Max
-0.33764 -0.01388  0.00130  0.01304  0.28572

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  4.063e-02  1.127e-02   3.606 0.000350 ***
y.l1         9.649e-01  8.385e-03 115.079 < 2e-16 ***
trend       -7.617e-06  3.065e-05  -0.249 0.803856
y.d11       5.091e-02  4.675e-02   1.089 0.276801
y.d12       1.316e-01  4.679e-02   2.812 0.005163 **
y.d13       2.954e-01  4.722e-02   6.257 9.9e-10 ***
du          4.296e-02  1.239e-02   3.467 0.000581 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04464 on 409 degrees of freedom
(4 observations deleted due to missingness)
Multiple R-squared:  0.9937, Adjusted R-squared:  0.9936
F-statistic: 1.075e+04 on 6 and 409 DF,  p-value: < 2.2e-16

Teststatistic: -4.1829
Critical values: 0.01= -5.34 0.05= -4.8 0.1= -4.58

Potential break point at position: 349

> AIC(eval(attributes(lngas.za)$testreg))
[1] -1397.29
> BIC(eval(attributes(lngas.za)$testreg))
[1] -1365.044
>
> lncoal.za=ur.za(lncoal,model="intercept",lag=3)
> summary(lncoal.za)

#####
# Zivot-Andrews Unit Root Test #
#####

Call:
lm(formula = testmat)

Residuals:
    Min       1Q   Median       3Q      Max
-0.25593 -0.01657  0.00202  0.01512  0.35704

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.619e-01  3.660e-02   4.423 1.25e-05 ***

```

```

y.l1      9.564e-01  9.868e-03  96.915 < 2e-16 ***
trend    -5.700e-05  3.784e-05  -1.506 0.132730
y.d11    2.685e-01  4.756e-02  5.645 3.09e-08 ***
y.d12    4.271e-02  4.930e-02  0.866 0.386821
y.d13    4.560e-02  4.776e-02  0.955 0.340257
du        5.006e-02  1.315e-02  3.806 0.000163 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.05309 on 409 degrees of freedom
(4 observations deleted due to missingness)
Multiple R-squared:  0.9862, Adjusted R-squared:  0.986
F-statistic: 4886 on 6 and 409 DF, p-value: < 2.2e-16

Teststatistic: -4.4177
Critical values: 0.01= -5.34 0.05= -4.8 0.1= -4.58

Potential break point at position: 344

> AIC(eval(attributes(lncoal.za)$testreg))
[1] -1253.027
> BIC(eval(attributes(lncoal.za)$testreg))
[1] -1220.782

```

### Appendix 21: Kwiatkowski–Phillips–Schmidt–Shin unit root test *R* code.

```

> lnoil.kpss=ur.kpss(lnoil, type ="tau",use.lag=1)
> summary(lnoil.kpss)

#####
# KPSS Unit Root Test #
#####

Test is of type: tau with 1 lags.

Value of test-statistic is: 4.2222

Critical value for a significance level of:
          10pct  5pct  2.5pct  1pct
critical values 0.119 0.146  0.176 0.216

> lngas.kpss=ur.kpss(lngas, type ="tau",use.lag=1)
> summary(lngas.kpss)

#####
# KPSS Unit Root Test #
#####

Test is of type: tau with 1 lags.

Value of test-statistic is: 4.2524

Critical value for a significance level of:
          10pct  5pct  2.5pct  1pct
critical values 0.119 0.146  0.176 0.216

> lncoal.kpss=ur.kpss(lncoal, type ="mu",use.lag=1)
> summary(lncoal.kpss)

```

```
#####
# KPSS Unit Root Test #
#####

Test is of type: mu with 1 lags.

Value of test-statistic is: 9.0657

Critical value for a significance level of:
      10pct  5pct  2.5pct  1pct
critical values 0.347 0.463  0.574 0.739
```

## Appendix 22: ADF order of integration test R code.

```
> dlnoil=diff(lnoil)
> dlngas=diff(lngas)
> dlncoal=diff(lncoal)
>
> dlnoil.ct=ur.df(dlnoil,type='none',selectlags="AIC")
> summary(dlnoil.ct)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression none

Call:
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
    Min       1Q   Median       3Q      Max
-0.28584 -0.04167  0.00196  0.04803  0.42621

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
z.lag.1      -0.73800    0.05868  -12.576 <2e-16 ***
z.diff.lag   0.05722    0.04943   1.158  0.248
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07793 on 415 degrees of freedom
Multiple R-squared:  0.3464, Adjusted R-squared:  0.3433
F-statistic:  110 on 2 and 415 DF,  p-value: < 2.2e-16

Value of test-statistic is: -12.5757

Critical values for test statistics:
      1pct  5pct 10pct
tau1 -2.58 -1.95 -1.62

>
> dlngas.ct=ur.df(dlngas,type='none',selectlags="AIC")
> summary(dlngas.ct)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####
```

Test regression none

Call:

```
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
```

Residuals:

Min	1Q	Median	3Q	Max
-0.34307	-0.00771	0.00000	0.01118	0.29957

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
z.lag.1	-0.74411	0.06465	-11.510	< 2e-16 ***
z.diff.lag	-0.16044	0.04901	-3.274	0.00115 **

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04721 on 415 degrees of freedom

Multiple R-squared: 0.4538, Adjusted R-squared: 0.4511

F-statistic: 172.4 on 2 and 415 DF, p-value: < 2.2e-16

Value of test-statistic is: -11.51

Critical values for test statistics:

	1pct	5pct	10pct
tau1	-2.58	-1.95	-1.62

>

```
> dlncoal.ct=ur.df(dlncoal,type='none',selectlags="AIC")
```

```
> summary(dlncoal.ct)
```

```
#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####
```

Test regression none

Call:

```
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
```

Residuals:

Min	1Q	Median	3Q	Max
-0.27442	-0.01258	0.00000	0.01131	0.35842

Coefficients:

	Estimate	Std. Error	t value	Pr(> t )
z.lag.1	-0.68153	0.05855	-11.640	<2e-16 ***
z.diff.lag	-0.04359	0.04905	-0.889	0.375

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.05493 on 415 degrees of freedom

Multiple R-squared: 0.3575, Adjusted R-squared: 0.3544

F-statistic: 115.5 on 2 and 415 DF, p-value: < 2.2e-16

Value of test-statistic is: -11.6396

```
Critical values for test statistics:
```

```
    1pct  5pct 10pct
tau1 -2.58 -1.95 -1.62
```

### Appendix 23: Ganger-Causality test R code.

```
> # l=1
>
> grangertest(dlnoil~dlngas, order=1)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:1) + Lags(dlngas, 1:1)
Model 2: dlnoil ~ Lags(dlnoil, 1:1)
  Res.Df Df      F Pr(>F)
1     415
2     416 -1 0.1212 0.7279
> grangertest(dlnoil~dlncoal, order=1)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:1) + Lags(dlncoal, 1:1)
Model 2: dlnoil ~ Lags(dlnoil, 1:1)
  Res.Df Df      F Pr(>F)
1     415
2     416 -1 4.527 0.03395 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlngas~dlnoil, order=1)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:1) + Lags(dlnoil, 1:1)
Model 2: dlngas ~ Lags(dlngas, 1:1)
  Res.Df Df      F Pr(>F)
1     415
2     416 -1 0.0376 0.8464
> grangertest(dlngas~dlncoal, order=1)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:1) + Lags(dlncoal, 1:1)
Model 2: dlngas ~ Lags(dlngas, 1:1)
  Res.Df Df      F Pr(>F)
1     415
2     416 -1 3.7662 0.05298 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlncoal~dlnoil, order=1)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:1) + Lags(dlnoil, 1:1)
Model 2: dlncoal ~ Lags(dlncoal, 1:1)
  Res.Df Df      F Pr(>F)
1     415
2     416 -1 3.2506 0.07212 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlncoal~dlnlngas, order=1)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:1) + Lags(dlnlngas, 1:1)
Model 2: dlncoal ~ Lags(dlncoal, 1:1)
  Res.Df Df      F Pr(>F)
```

```

1 415
2 416 -1 1.6341 0.2019
>
> # l=2
>
> grangertest(dlnoil~dlngas, order=2)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:2) + Lags(dlngas, 1:2)
Model 2: dlnoil ~ Lags(dlnoil, 1:2)
  Res.Df Df      F Pr(>F)
1 412
2 414 -2 0.7421 0.4767
> grangertest(dlnoil~dlncoal, order=2)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:2) + Lags(dlncoal, 1:2)
Model 2: dlnoil ~ Lags(dlnoil, 1:2)
  Res.Df Df      F Pr(>F)
1 412
2 414 -2 2.5162 0.08201 .
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlngas~dlnoil, order=2)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:2) + Lags(dlnoil, 1:2)
Model 2: dlngas ~ Lags(dlngas, 1:2)
  Res.Df Df      F Pr(>F)
1 412
2 414 -2 3.913 0.02073 *
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlngas~dlncoal, order=2)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:2) + Lags(dlncoal, 1:2)
Model 2: dlngas ~ Lags(dlngas, 1:2)
  Res.Df Df      F Pr(>F)
1 412
2 414 -2 4.8271 0.008468 **
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlncoal~dlnoil, order=2)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:2) + Lags(dlnoil, 1:2)
Model 2: dlncoal ~ Lags(dlncoal, 1:2)
  Res.Df Df      F Pr(>F)
1 412
2 414 -2 2.0349 0.132
> grangertest(dlncoal~dlnlngas, order=2)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:2) + Lags(dlnlngas, 1:2)
Model 2: dlncoal ~ Lags(dlncoal, 1:2)
  Res.Df Df      F Pr(>F)
1 412
2 414 -2 0.8074 0.4467
>
> # l=3
>

```

```

> grangertest(dlnoil~dlngas, order=3)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:3) + Lags(dlngas, 1:3)
Model 2: dlnoil ~ Lags(dlnoil, 1:3)
  Res.Df Df      F Pr(>F)
1      409
2      412 -3 0.8279 0.479
> grangertest(dlnoil~dlncoal, order=3)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:3) + Lags(dlncoal, 1:3)
Model 2: dlnoil ~ Lags(dlnoil, 1:3)
  Res.Df Df      F Pr(>F)
1      409
2      412 -3 1.6872 0.1691
> grangertest(dlngas~dlnoil, order=3)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:3) + Lags(dlnoil, 1:3)
Model 2: dlngas ~ Lags(dlngas, 1:3)
  Res.Df Df      F Pr(>F)
1      409
2      412 -3 7.5596 6.22e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlngas~dlncoal, order=3)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:3) + Lags(dlncoal, 1:3)
Model 2: dlngas ~ Lags(dlngas, 1:3)
  Res.Df Df      F Pr(>F)
1      409
2      412 -3 2.9932 0.03074 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlncoal~dlnoil, order=3)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:3) + Lags(dlnoil, 1:3)
Model 2: dlncoal ~ Lags(dlncoal, 1:3)
  Res.Df Df      F Pr(>F)
1      409
2      412 -3 1.651 0.1771
> grangertest(dlncoal~dlngas, order=3)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:3) + Lags(dlngas, 1:3)
Model 2: dlncoal ~ Lags(dlncoal, 1:3)
  Res.Df Df      F Pr(>F)
1      409
2      412 -3 1.1996 0.3096
>
> # l=4
>
> grangertest(dlnoil~dlngas, order=4)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:4) + Lags(dlngas, 1:4)
Model 2: dlnoil ~ Lags(dlnoil, 1:4)
  Res.Df Df      F Pr(>F)
1      406

```

```

2    410 -4 0.5182 0.7224
> grangertest(dlnoil~dlncoal, order=4)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:4) + Lags(dlncoal, 1:4)
Model 2: dlnoil ~ Lags(dlnoil, 1:4)
  Res.Df Df      F Pr(>F)
1     406
2     410 -4 1.4063 0.2311
> grangertest(dlngas~dlnoil, order=4)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:4) + Lags(dlnoil, 1:4)
Model 2: dlngas ~ Lags(dlngas, 1:4)
  Res.Df Df      F Pr(>F)
1     406
2     410 -4 12.2 2.242e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlngas~dlncoal, order=4)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:4) + Lags(dlncoal, 1:4)
Model 2: dlngas ~ Lags(dlngas, 1:4)
  Res.Df Df      F Pr(>F)
1     406
2     410 -4 5.0361 0.00057 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlncoal~dlnoil, order=4)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:4) + Lags(dlnoil, 1:4)
Model 2: dlncoal ~ Lags(dlncoal, 1:4)
  Res.Df Df      F Pr(>F)
1     406
2     410 -4 1.2623 0.2842
> grangertest(dlncoal~dlngas, order=4)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:4) + Lags(dlngas, 1:4)
Model 2: dlncoal ~ Lags(dlncoal, 1:4)
  Res.Df Df      F Pr(>F)
1     406
2     410 -4 1.0271 0.3929
>
> # l=5
>
> grangertest(dlnoil~dlngas, order=5)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:5) + Lags(dlngas, 1:5)
Model 2: dlnoil ~ Lags(dlnoil, 1:5)
  Res.Df Df      F Pr(>F)
1     403
2     408 -5 0.3918 0.8545
> grangertest(dlnoil~dlncoal, order=5)
Granger causality test

Model 1: dlnoil ~ Lags(dlnoil, 1:5) + Lags(dlncoal, 1:5)
Model 2: dlnoil ~ Lags(dlnoil, 1:5)
  Res.Df Df      F Pr(>F)

```

```

1 403
2 408 -5 1.5496 0.1734
> grangertest(dlngas~dlnoil, order=5)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:5) + Lags(dlnoil, 1:5)
Model 2: dlngas ~ Lags(dlngas, 1:5)
  Res.Df Df      F    Pr(>F)
1     403
2     408 -5 9.8485 6.76e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlngas~dlncoal, order=5)
Granger causality test

Model 1: dlngas ~ Lags(dlngas, 1:5) + Lags(dlncoal, 1:5)
Model 2: dlngas ~ Lags(dlngas, 1:5)
  Res.Df Df      F    Pr(>F)
1     403
2     408 -5 4.149 0.001096 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> grangertest(dlncoal~dlnoil, order=5)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:5) + Lags(dlnoil, 1:5)
Model 2: dlncoal ~ Lags(dlncoal, 1:5)
  Res.Df Df      F    Pr(>F)
1     403
2     408 -5 1.3273 0.2516
> grangertest(dlncoal~dln gas, order=5)
Granger causality test

Model 1: dlncoal ~ Lags(dlncoal, 1:5) + Lags(dlngas, 1:5)
Model 2: dlncoal ~ Lags(dlncoal, 1:5)
  Res.Df Df      F    Pr(>F)
1     403
2     408 -5 0.9018 0.4798

```

#### Appendix 24: Linear regressions (Engle-Granger) R code.

```

> lnoil=ts(lnoil,start=c(1980,1), end=c(2014,12), frequency = 12)
> lngas=ts(lngas,start=c(1980,1), end=c(2014,12), frequency = 12)
> lncoal=ts(lncoal,start=c(1980,1), end=c(2014,12), frequency = 12)
>
> oc.eq=summary(lm(lnoil~lncoal))
> oc.eq

Call:
lm(formula = lnoil ~ lncoal)

Residuals:
    Min       1Q   Median       3Q      Max
-0.74983 -0.30975 -0.04285  0.27903  0.76139

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -1.37139    0.14826   -9.25  <2e-16 ***
lncoal       1.27876    0.03883   32.93  <2e-16 ***
---

```

```

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3561 on 418 degrees of freedom
Multiple R-squared:  0.7218, Adjusted R-squared:  0.7211
F-statistic: 1084 on 1 and 418 DF,  p-value: < 2.2e-16

>
> go.eq=summary(lm(lngas~lnoil))
> go.eq

Call:
lm(formula = lngas ~ lnoil)

Residuals:
    Min       1Q   Median       3Q      Max
-0.48385 -0.08329 -0.01738  0.05152  1.09581

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -1.24474    0.04685  -26.57  <2e-16 ***
lnoil         0.77842    0.01323   58.84  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1826 on 418 degrees of freedom
Multiple R-squared:  0.8923, Adjusted R-squared:  0.892
F-statistic: 3462 on 1 and 418 DF,  p-value: < 2.2e-16

>
> gc.eq=summary(lm(lngas~lncoal))
> gc.eq

Call:
lm(formula = lngas ~ lncoal)

Residuals:
    Min       1Q   Median       3Q      Max
-0.56373 -0.24353 -0.03788  0.22293  0.77841

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -2.50343    0.12453  -20.10  <2e-16 ***
lncoal       1.04584    0.03262   32.06  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2991 on 418 degrees of freedom
Multiple R-squared:  0.7109, Adjusted R-squared:  0.7102
F-statistic: 1028 on 1 and 418 DF,  p-value: < 2.2e-16

```

### Appendix 25: Residuals extraction R code.

```

> error.oc.eq=ts(resid(oc.eq),start=c(1980,2), end=c(2014,12), frequency = 12)
> error.go.eq=ts(resid(go.eq),start=c(1980,2), end=c(2014,12), frequency = 12)
> error.gc.eq=ts(resid(gc.eq),start=c(1980,2), end=c(2014,12), frequency = 12)

```

Appendix 26: ADF unit root test on residuals (Engle-Granger) *R* code.

```

> ci.oc=ur.df(error.oc.eq, type='none',selectlags="AIC")
> summary(ci.oc)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression none

Call:
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
    Min       1Q   Median       3Q      Max
-0.42803 -0.05341  0.00010  0.05085  0.37716

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
z.lag.1      -0.04561    0.01313   -3.475 0.000566 ***
z.diff.lag   0.19984    0.04806    4.158 3.9e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.09418 on 415 degrees of freedom
Multiple R-squared:  0.05892,    Adjusted R-squared:  0.05438
F-statistic: 12.99 on 2 and 415 DF,  p-value: 3.37e-06

Value of test-statistic is: -3.4745

Critical values for test statistics:
      1pct  5pct 10pct
tau1 -2.58 -1.95 -1.62

>
> ci.go=ur.df(error.go.eq, type='none',selectlags="AIC")
> summary(ci.go)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression none

Call:
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
    Min       1Q   Median       3Q      Max
-0.37811 -0.04034 -0.00236  0.03698  0.33059

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
z.lag.1      -0.12666    0.02063   -6.141 1.92e-09 ***
z.diff.lag   0.29980    0.04676    6.411 3.94e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```

Residual standard error: 0.07481 on 415 degrees of freedom
Multiple R-squared: 0.1349, Adjusted R-squared: 0.1307
F-statistic: 32.36 on 2 and 415 DF, p-value: 8.701e-14

Value of test-statistic is: -6.1407

Critical values for test statistics:
      1pct  5pct 10pct
tau1 -2.58 -1.95 -1.62

>
> ci.gc=ur.df(error.gc.eq, type='none',selectlags="AIC")
> summary(ci.gc)

#####
# Augmented Dickey-Fuller Test Unit Root Test #
#####

Test regression none

Call:
lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)

Residuals:
      Min       1Q   Median       3Q      Max
-0.38078 -0.02390 -0.00277  0.02480  0.37409

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
z.lag.1      -0.03732    0.01230  -3.033 0.002570 **
z.diff.lag   0.16566    0.04850   3.415 0.000699 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07415 on 415 degrees of freedom
Multiple R-squared: 0.04259, Adjusted R-squared: 0.03798
F-statistic: 9.231 on 2 and 415 DF, p-value: 0.0001196

Value of test-statistic is: -3.0334

Critical values for test statistics:
      1pct  5pct 10pct
tau1 -2.58 -1.95 -1.62

```

Appendix 27: ECM Engle-Granger  $R$  code.

```

> dlnoil=diff(lnoil)
> dlngas=diff(lngas)
> dlncoal=diff(lncoal)
>
> lerror.oc.eq=lag(error.oc.eq)
> lerror.go.eq=lag(error.go.eq)
> lerror.gc.eq=lag(error.gc.eq)
>
> ecm.oc.eq=summary(lm(dlnoil~dlncoal+lerror.oc.eq))
> ecm.oc.eq

Call:
lm(formula = dlnoil ~ dlncoal + lerror.oc.eq)

Residuals:
    Min       1Q   Median       3Q      Max
-0.26409 -0.04299  0.00545  0.04848  0.36881

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.0005864  0.0038910   2.151  0.0023 **
dlncoal      0.3180181  0.0687312   4.627 4.96e-06 ***
lerror.oc.eq -0.0196971  0.0110405  -1.784  0.0751 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07961 on 416 degrees of freedom
Multiple R-squared:  0.05193,    Adjusted R-squared:  0.04737
F-statistic: 11.39 on 2 and 416 DF,  p-value: 1.524e-05

> ecm.go.eq=summary(lm(dlngas~dlnoil+lerror.go.eq))
> ecm.go.eq

Call:
lm(formula = dlngas ~ dlnoil + lerror.go.eq)

Residuals:
    Min       1Q   Median       3Q      Max
-0.303048 -0.012939 -0.003201  0.012468  0.265161

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.001976  0.002164   8.914 3.23e-06 ***
dlnoil      -0.029021  0.026555  -5.093 2.03e-04 ***
lerror.go.eq -0.101288  0.011902  -8.510 3.19e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04428 on 416 degrees of freedom
Multiple R-squared:  0.15, Adjusted R-squared:  0.1459
F-statistic: 36.72 on 2 and 416 DF,  p-value: 2.069e-15

> ecm.gc.eq=summary(lm(dlngas~dlncoal+lerror.gc.eq))
> ecm.gc.eq

Call:
lm(formula = dlngas ~ dlncoal + lerror.gc.eq)

Residuals:

```

```

      Min      1Q   Median      3Q      Max
-0.34023 -0.01055 -0.00185  0.01018  0.28744

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.001956   0.002332   3.839  0.0022 **
dlncoal      0.027130   0.040903   3.663  0.0075 **
lerror.gc.eq -0.018055   0.007841  -2.303  0.0218 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04771 on 416 degrees of freedom
Multiple R-squared:  0.01321,    Adjusted R-squared:  0.008468
F-statistic: 2.785 on 2 and 416 DF,  p-value: 0.06289

```

### Appendix 28: Diagnostic tests on residuals (Engle-Granger) *R* code.

```

> library(tseries)
> library(FinTS)
>
> jarque.bera.test(lag(error.oc.eq))

      Jarque Bera Test

data:  lag(error.oc.eq)
X-squared = 23.848, df = 2, p-value = 6.628e-06

> ArchTest(lag(error.oc.eq),lags=3)

      ARCH LM-test; Null hypothesis: no ARCH effects

data:  lag(error.oc.eq)
Chi-squared = 306.33, df = 3, p-value < 2.2e-16

> Box.test(lag(error.oc.eq),lag=1,type="Ljung-Box")

      Box-Ljung test

data:  lag(error.oc.eq)
X-squared = 387.08, df = 1, p-value < 2.2e-16

>
> jarque.bera.test(lag(lerror.go.eq))

      Jarque Bera Test

data:  lag(lerror.go.eq)
X-squared = 1381.1, df = 2, p-value < 2.2e-16

> ArchTest(lag(lerror.go.eq),lags=3)

      ARCH LM-test; Null hypothesis: no ARCH effects

data:  lag(lerror.go.eq)
Chi-squared = 334.78, df = 3, p-value < 2.2e-16

> Box.test(lag(lerror.go.eq),lag=1,type="Ljung-Box")

      Box-Ljung test

```

```

data: lag(lerror.go.eq)
X-squared = 343.14, df = 1, p-value < 2.2e-16

>
> jarque.bera.test(lag(error.gc.eq))

        Jarque Bera Test

data: lag(error.gc.eq)
X-squared = 16.905, df = 2, p-value = 0.0002133

> ArchTest(lag(error.gc.eq),lags=3)

        ARCH LM-test; Null hypothesis: no ARCH effects

data: lag(error.gc.eq)
Chi-squared = 339.36, df = 3, p-value < 2.2e-16

> Box.test(lag(error.gc.eq),lag=1,type="Ljung-Box")

        Box-Ljung test

data: lag(error.gc.eq)
X-squared = 392.97, df = 1, p-value < 2.2e-16

```

### Appendix 29: Lag length selection (Johansen) *R* code.

```

> VARselect(data.frame(lnoil,lngas,lncoal))
$selection
AIC(n)  HQ(n)  SC(n)  FPE(n)
   4      2      2      4

```

### Appendix 30: Trace test *R* code.

```

> summary(ca.jo(data.frame(lnoil,lngas,lncoal), type="trace", ecdet="const",K=2))

#####
# Johansen-Procedure #
#####

Test type: trace statistic , without linear trend and constant in cointegration

Eigenvalues (lambda):
[1] 1.897351e-01 2.657437e-02 2.416389e-03 1.105987e-17

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 2 |   1.01  7.52  9.24 12.97
r <= 1 |  12.27 17.85 19.96 24.60
r = 0  | 100.21 32.00 34.91 41.07

Eigenvectors, normalised to first column:
(These are the cointegration relations)

          lnoil.l2 lngas.l2 lncoal.l2 constant
lnoil.l2  1.00000000  1.000000  1.0000000  1.0000000
lngas.l2 -1.10665495  1.743131  4.8563833 -2.9781347
lncoal.l2 -0.07581553 -4.230961 -0.3565082 -0.5939847

```

```

constant -1.55323229 10.064950 -10.7416858 0.5819703

Weights w:
(This is the loading matrix)

      lnoil.l2  lngas.l2  lncoal.l2  constant
lnoil.d -0.055668074 -0.001718585 -0.0010045293 -1.024717e-18
lngas.d 0.099687947 -0.001420345 -0.0001612716 -1.685653e-17
lncoal.d 0.009784644 0.008624744 -0.0002500193 -1.846664e-18

```

### Appendix 31: Maximum eigenvalue test *R* code.

```

> summary(ca.jo(data.frame(lnoil,lngas,lncoal), type="eigen", ecdet="const",k=2))

#####
# Johansen-Procedure #
#####

Test type: maximal eigenvalue statistic (lambda max) , without linear trend and constant in co
integration

Eigenvalues (lambda):
[1] 1.897351e-01 2.657437e-02 2.416389e-03 1.105987e-17

Values of teststatistic and critical values of test:

      test 10pct 5pct 1pct
r <= 2 | 1.01 7.52 9.24 12.97
r <= 1 | 11.26 13.75 15.67 20.20
r = 0 | 87.94 19.77 22.00 26.81

Eigenvectors, normalised to first column:
(These are the cointegration relations)

      lnoil.l2  lngas.l2  lncoal.l2  constant
lnoil.l2 1.00000000 1.000000 1.0000000 1.0000000
lngas.l2 -1.10665495 1.743131 4.8563833 -2.9781347
lncoal.l2 -0.07581553 -4.230961 -0.3565082 -0.5939847
constant -1.55323229 10.064950 -10.7416858 0.5819703

Weights w:
(This is the loading matrix)

      lnoil.l2  lngas.l2  lncoal.l2  constant
lnoil.d -0.055668074 -0.001718585 -0.0010045293 -1.024717e-18
lngas.d 0.099687947 -0.001420345 -0.0001612716 -1.685653e-17
lncoal.d 0.009784644 0.008624744 -0.0002500193 -1.846664e-18

```

Appendix 32: Vector error correction model (Johansen) R code.

```

> library(vars)
>
> vecm.eigen<-ca.jo(data.frame(lnoil,lngas,lncoal), type="eigen",ecdet="const", K=2)
>
> vecm.model<-cajorls(vecm.eigen,r=1)
>
> vecm.model
$r1m

Call:
lm(formula = substitute(form1), data = data.mat)

Coefficients:
          lnoil.d      lngas.d      lncoal.d
ect1      -0.055668   -0.099688   -0.009785
lnoil.d11    0.276818   -0.001941    0.063533
lngas.d11    0.068040   -0.068597    0.058959
lncoal.d11   0.169489    0.039345    0.262528

$beta
          ect1
lnoil.l12  1.00000000
lngas.l12 -1.10665495
lncoal.l12 -0.07581553
constant  -1.55323229

Response lnoil.d :
      Estimate Std. Error  t value    Pr(>|t|)
ect1      -0.05566807 0.01905455  -2.9215110 3.674088e-03
lnoil.d11  0.27681826 0.04767923  5.8058452 1.276390e-08
lngas.d11  0.06803976 0.08621178  0.7892165 4.304372e-01
lncoal.d11 0.16948881 0.06785861  2.4976759 1.288824e-02

Response lngas.d :
      Estimate Std. Error  t value    Pr(>|t|)
ect1      -0.099687947 0.01073679  9.28470785 9.234033e-19
lnoil.d11 -0.001940856 0.02686612 -3.07224174 9.424444e-03
lngas.d11 -0.068597421 0.04857831 -2.41209991 1.586717e-02
lncoal.d11 0.039344749 0.03823672  2.02897804 3.040908e-02

Response lncoal.d :
      Estimate Std. Error  t value    Pr(>|t|)
ect1      -0.019784644 0.01354162  0.7225607 4.703578e-01
lnoil.d11 0.063533383 0.03388451  1.8749977 6.149679e-02
lngas.d11 0.058959376 0.06126869  0.9623084 3.364564e-01
lncoal.d11 0.262527655 0.04822552  5.4437496 8.955941e-08

```

Appendix 33: Structural shift *R* code.

```

> summary(cajolst(data.frame(lnoil,lngas,lncoal),trend=FALSE, k=2))

#####
# Johansen-Procedure #
#####

Test type: trace statistic , without linear trend in shift correction

Eigenvalues (lambda):
[1] 0.20119298 0.02865856 0.01893114

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 2 |  2.84  3.00  4.12  6.89
r <= 1 | 19.65 10.45 12.28 16.42
r = 0  | 96.28 21.80 24.28 29.47

Eigenvectors, normalised to first column:
(These are the cointegration relations)

          lnoil.l1  lngas.l1  lncoal.l1
lnoil.l1  1.00000000  1.000000  1.000000
lngas.l1  -1.09406836  1.264131  2.871116
lncoal.l1 -0.04126493 -6.348730 -1.779604

weights w:
(This is the loading matrix)

          lnoil.l1  lngas.l1  lncoal.l1
lnoil  0.02052543  4.063043e-03 -0.0098151159
lngas  0.15720234  6.172456e-05 -0.0026674683
lncoal 0.06015966  6.895108e-03 -0.0004492599

```

Appendix 34: Vector error correction model (Structural shift) *R* code.

```

> vecm.break<-ca.jo(data.frame(lnoil,lngas,lncoal), type="eigen",ecdet="const", k=2)
>
> vecm.model2<-cajorls(vecm.break,r=2)
> vecm.model2
$rlm

Call:
lm(formula = substitute(form1), data = data.mat)

Coefficients:
          lnoil.d      lngas.d      lncoal.d
ect1      -0.057387   -0.098268   -0.018409
ect2      -0.058610   -0.112796   -0.004206
lnoil.d11    0.275549   -0.002990    0.069905
lngas.d11    0.066484   -0.069883    0.066767
lncoal.d11   0.173342    0.042530    0.243189

$beta
          ect1      ect2
lnoil.l2  1.000000  1.665335e-16
lngas.l2  0.000000  1.000000e+00
lncoal.l2 -1.689380 -1.458055e+00
constant  2.958446  4.076861e+00

Response lnoil.d :
          Estimate Std. Error  t value  Pr(>|t|)
ect1      -0.05738666  0.01946639 -2.9479862  3.380028e-03
ect2      -0.05860963  0.02217150  2.6434676  8.518506e-03
lnoil.d11  0.27554865  0.04781225  5.7631392  1.617018e-08
lngas.d11  0.06648398  0.08636768  0.7697784  4.418714e-01
lncoal.d11 0.17334232  0.06848335  2.5311600  1.173877e-02

Response lngas.d :
          Estimate Std. Error  t value  Pr(>|t|)
ect1      -0.098267601  0.01096587  8.9612192  1.117583e-17
ect2      -0.112796008  0.01248972 -9.0311070  6.564873e-18
lnoil.d11 -0.002990137  0.02693376 -3.1110182  9.116559e-03
lngas.d11 -0.069883218  0.04865293 -2.4363620  1.516564e-02
lncoal.d11 0.042529526  0.03857827  2.1024218  2.709203e-02

Response lncoal.d :
          Estimate Std. Error  t value  Pr(>|t|)
ect1      -0.018409388  0.01367390  1.3463160  1.789391e-01
ect2      -0.004205838  0.01557406  0.2700541  7.872535e-01
lnoil.d11 0.069904920  0.03358505  2.0814296  3.801001e-02
lngas.d11 0.066767104  0.06066778  1.1005365  2.717395e-01
lncoal.d11 0.243188773  0.04810518  5.0553554  6.468839e-07

```