Real-time Forecast Combinations for the Oil Price*

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Summary: Baumeister and Kilian (2015) combine forecasts from six empirical models to predict real oil prices. In this paper, we broadly reproduce their main economic findings, employing their preferred measures of the real oil price and other real-time variables. Mindful of the importance of Brent crude oil as a global price benchmark, we extend consideration to the North Sea based measure and update the evaluation sample to 2017:12. We model the oil price futures curve using a factor-based Nelson-Siegel specification estimated in real time to fill in missing values for oil price futures in the raw data. We find that the combined forecasts for Brent are as effective as for other oil price measures. The extended sample using the oil price measures adopted by Baumeister and Kilian (2015) yields similar results to those reported in their paper. And the futures-based model improves forecast accuracy at longer horizons. The real-time data set is available for download from *https://www.niesr.ac.uk/real-time-forecast-combinations-oil-price*.

Keywords: Real oil price forecasting, Brent crude oil, Forecast combination

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Appendix to Garratt, Vahey and Zhang (2018)

(I) Shorter evaluation sample, 1992:01–2012:09

Our results from the narrow replication, using the evaluation sample examined by Baumeister and Kilian (2015) are shown in Tables A-1a and A-1b. These results use the same WTI and RAC measures considered by those authors. The results confirm the main findings of their paper. Equal weight point combinations have lower MSPE ratios and higher success ratios than inverse MSPE weights for most horizons. The corresponding recursive MSPE and success ratios for the Brent measure, with the same 1992:01 to 2012:09 evaluation sample are displayed in Table A-1c.

Table A-1a. Forecast Accuracy for RAC, Evaluation 1992:01-2012:09

	Real U.S. refiners' acquisition cost for oil imports				
			Rolling weights based on windows of length		
MH	Equal weight	Recursive weights	36	24	12
			Recursive MSPE ratios		
1	**0.928****(0.028)	**0.933****(0.039)	**0.935****(0.045)	**0.928****(0.033)	**0.925****(0.030)
3	**0.922****(0.008)	**0.925****(0.009)	**0.925****(0.009)	**0.920****(0.005)	**0.925****(0.005)
6	**0.985**(0.172)	**0.989**(0.241)	**0.990**(0.254)	**0.991**(0.282)	**0.990**(0.251)
9	**0.980**(0.111)	**0.985**(0.182)	**0.983**(0.156)	**0.986**(0.212)	**0.988**(0.257)
12	**0.941****(0.001)	**0.946****(0.003)	**0.949****(0.006)	**0.947****(0.004)	**0.942****(0.002)
15	**0.932****(0.000)	**0.942****(0.002)	**0.955****(0.022)	**0.954****(0.018)	**0.970***(0.095)
18	**0.974***(0.073)	**0.994**(0.380)	1.023(0.854)	1.030(0.908)	1.055(0.983)
21	1.006(0.636)	1.028(0.947)	1.054(0.995)	1.062(0.996)	1.099(1.000)
24	**0.987**(0.224)	**0.997**(0.427)	**1.000**(0.499)	1.005(0.592)	1.046(0.962)
			Success ratios		
1	**0.562****(0.050)	**0.546**(0.119)	**0.546**(0.119)	**0.542**(0.153)	**0.546**(0.129)
3	**0.575****(0.034)	**0.583****(0.017)	**0.579****(0.026)	**0.591****(0.010)	**0.579****(0.026)
6	**0.545**(0.201)	**0.520**(0.487)	**0.520**(0.487)	**0.516**(0.531)	**0.512**(0.558)
9	**0.539**(0.171)	**0.548***(0.085)	**0.560***(0.051)	**0.539**(0.146)	**0.544**(0.113)
12	**0.639****(0.000)	**0.634****(0.000)	**0.643****(0.000)	**0.630****(0.000)	**0.664****(0.000)
15	**0.617****(0.000)	**0.574****(0.007)	**0.557****(0.038)	**0.553****(0.047)	**0.562****(0.048)
18	**0.573****(0.001)	**0.543****(0.010)	**0.522**(0.100)	0.491(0.363)	0.500(0.290)
21	**0.563****(0.006)	**0.515***(0.052)	**0.546****(0.027)	**0.533**(0.116)	0.498(0.502)
24	**0.553****(0.048)	**0.518**(0.105)	**0.549***(0.079)	**0.544**(0.156)	**0.531**(0.264)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey, Leybourne, and Newbold (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

Table A-1b. Forecast Accuracy for WTI, Evaluation 1992:01-2012:09

	Real WTI price				
			Rolling weights based on windows of length		
MH	Equal weight	Recursive weights	36	24	12
			Recursive MSPE ratios		
1	**0.904**∗∗(0.007)	**0.908**∗∗(0.008)	**0.909**∗∗(0.009)	**0.909**∗∗(0.011)	**0.906**∗∗(0.011)
3	**0.923**∗∗(0.010)	**0.926**∗∗(0.010)	**0.927**∗∗(0.012)	**0.927**∗∗(0.010)	**0.931**∗∗(0.011)
6	**0.988**(0.242)	**0.992**(0.314)	**0.993**(0.323)	**0.994**(0.363)	**0.998**(0.442)
9	**0.982**(0.146)	**0.988**(0.236)	**0.983**(0.170)	**0.987**(0.228)	**0.990**(0.296)
12	**0.948**∗∗(0.004)	**0.955**∗∗(0.011)	**0.954**∗∗(0.013)	**0.950**∗∗(0.007)	**0.943**∗∗(0.003)
15	**0.942**∗∗(0.002)	**0.956**∗∗(0.015)	**0.966**∗(0.070)	**0.966**∗(0.064)	**0.945**∗∗(0.009)
18	**0.973**∗(0.070)	**0.998**(0.465)	1.026(0.883)	1.043(0.963)	1.069(0.989)
21	1.004(0.599)	1.033(0.966)	1.056(0.993)	1.067(0.995)	1.082(0.998)
24	**0.979**(0.146)	1.000(0.505)	1.001(0.526)	1.009(0.648)	1.054(0.969)
			Success ratios		
1	**0.542**(0.201)	**0.546**(0.187)	**0.538**(0.267)	**0.550**(0.165)	**0.554**(0.131)
3	**0.551**(0.158)	**0.543**(0.220)	**0.543**(0.220)	**0.547**(0.198)	**0.530**(0.407)
6	**0.525**(0.425)	**0.516**(0.549)	**0.512**(0.593)	0.500(0.699)	0.488(0.827)
9	**0.552**∗(0.082)	**0.552**∗(0.075)	**0.564**∗∗(0.039)	**0.560**∗(0.054)	**0.535**(0.169)
12	**0.584**∗∗(0.005)	**0.563**∗∗(0.034)	**0.580**∗∗(0.012)	**0.592**∗∗(0.004)	**0.592**∗∗(0.003)
15	**0.587**∗∗(0.004)	**0.570**∗∗(0.016)	**0.557**∗∗(0.049)	**0.566**∗∗(0.035)	**0.566**∗∗(0.016)
18	**0.582**∗∗(0.001)	**0.556**∗∗(0.004)	**0.530**∗(0.073)	**0.522**(0.133)	**0.522**(0.133)
21	**0.581**∗∗(0.003)	**0.511**∗(0.062)	**0.533**∗(0.051)	**0.528**(0.177)	**0.511**(0.324)
24	**0.540**(0.108)	0.482(0.433)	**0.531**(0.185)	**0.518**(0.430)	**0.527**(0.301)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. ∗ denotes significance at the 10% level and ∗∗ at the 5% level.

Table A-1c. Forecast Accuracy for Brent, Evaluation 1992:01-2012:09

	Real Brent price				
			Rolling weights based on windows of length		
MH	Equal weight	Recursive weights	36	24	12
			Recursive MSPE ratios		
1	**0.956**(0.110)	**0.935**∗∗(0.019)	**0.933**∗∗(0.019)	**0.936**∗∗(0.024)	**0.948**∗(0.086)
3	**0.941**∗∗(0.024)	**0.940**∗∗(0.017)	**0.938**∗∗(0.014)	**0.943**∗∗(0.021)	**0.945**∗∗(0.022)
6	**0.995**(0.394)	1.001(0.517)	1.005(0.632)	1.005(0.620)	1.008(0.689)
9	**0.983**(0.176)	**0.990**(0.278)	**0.990**(0.280)	**0.996**(0.395)	**0.996**(0.410)
12	**0.952**∗∗(0.003)	**0.961**∗∗(0.015)	**0.965**∗∗(0.022)	**0.966**∗∗(0.022)	**0.956**∗∗(0.010)
15	**0.947**∗∗(0.001)	**0.961**∗∗(0.013)	**0.972**∗(0.066)	**0.979**(0.112)	**0.980**(0.117)
18	**0.986**(0.203)	1.011(0.737)	1.032(0.963)	1.045(0.995)	1.077(1.000)
21	1.018(0.898)	1.044(0.998)	1.062(1.000)	1.068(1.000)	1.096(1.000)
24	1.014(0.799)	1.030(0.962)	1.039(0.985)	1.046(0.996)	1.101(1.000)
			Success ratios		
1	**0.514**(0.199)	**0.530**(0.110)	**0.530**(0.120)	**0.534**∗(0.099)	**0.550**∗∗(0.029)
3	**0.538**(0.134)	**0.522**(0.263)	**0.543**(0.104)	**0.538**(0.125)	**0.543**(0.104)
6	0.496(0.552)	0.480(0.727)	0.480(0.743)	0.471(0.764)	0.488(0.615)
9	**0.506**(0.315)	**0.510**(0.261)	**0.506**(0.315)	0.490(0.498)	0.498(0.352)
12	**0.567**∗∗(0.005)	**0.571**∗∗(0.005)	**0.576**∗∗(0.003)	**0.563**∗∗(0.006)	**0.584**∗∗(0.001)
15	**0.583**∗∗(0.001)	**0.596**∗∗(0.000)	**0.604**∗∗(0.000)	**0.587**∗∗(0.000)	**0.609**∗∗(0.000)
18	**0.543**∗∗(0.002)	**0.543**∗∗(0.000)	0.500∗(0.052)	0.483(0.221)	0.466(0.389)
21	**0.528**∗∗(0.003)	**0.502**∗∗(0.006)	**0.507**∗∗(0.021)	0.463(0.427)	0.445(0.621)
24	0.491(0.253)	0.456(0.461)	0.500(0.120)	0.442(0.870)	0.451(0.819)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. ∗ denotes significance at the 10% level and ∗∗ at the 5% level.

(II) Longer evaluation sample, 1992:01–2017:12, for RAC and WTI measures

We also present the forecast accuracy of RAC and WTI for the extended 1992:01 to 2017:12 evaluation sample in Tables A-2a and A-2b, respectively.

Table A-2a. Forecast Accuracy for RAC, Evaluation 1992:01 to 2017:12

	Real U.S. refiners' acquisition cost for oil imports				
			Rolling weights based on windows of length		
MH	Equal weight	Recursive weights	36	24	12
			Recursive MSPE ratios		
1	**0.931****(0.015)	**0.935****(0.022)	**0.939****(0.029)	**0.932****(0.020)	**0.928****(0.016)
3	**0.923****(0.002)	**0.925****(0.002)	**0.930****(0.004)	**0.922****(0.001)	**0.921****(0.001)
6	**0.977****(0.048)	**0.983***(0.099)	**0.984**(0.100)	**0.979***(0.058)	**0.971****(0.025)
9	**0.971****(0.015)	**0.978***(0.058)	**0.974****(0.030)	**0.972****(0.029)	**0.969****(0.026)
12	**0.936****(0.000)	**0.945****(0.000)	**0.941****(0.000)	**0.930****(0.000)	**0.921****(0.000)
15	**0.932****(0.000)	**0.944****(0.000)	**0.944****(0.001)	**0.935****(0.000)	**0.927****(0.000)
18	**0.944****(0.000)	**0.963****(0.009)	**0.974***(0.078)	**0.972***(0.079)	**0.951****(0.042)
21	**0.972****(0.022)	**0.998**(0.429)	**0.998**(0.456)	1.001(0.528)	**0.994**(0.419)
24	**0.970****(0.024)	1.012(0.798)	**0.989**(0.248)	**0.991**(0.293)	1.006(0.586)
			Success ratios		
1	**0.558****(0.042)	**0.545***(0.095)	**0.564****(0.024)	**0.554***(0.053)	**0.561****(0.033)
3	**0.597****(0.002)	**0.594****(0.002)	**0.600****(0.001)	**0.606****(0.000)	**0.606****(0.000)
6	**0.573****(0.021)	**0.547**(0.150)	**0.550**(0.111)	**0.554***(0.081)	**0.554***(0.077)
9	**0.549***(0.068)	**0.556****(0.038)	**0.582****(0.003)	**0.569****(0.012)	**0.569****(0.011)
12	**0.645****(0.000)	**0.631****(0.000)	**0.654****(0.000)	**0.645****(0.000)	**0.681****(0.000)
15	**0.614****(0.000)	**0.581****(0.004)	**0.570****(0.012)	**0.584****(0.003)	**0.581****(0.004)
18	**0.586****(0.001)	**0.556****(0.016)	**0.536***(0.092)	**0.508**(0.348)	**0.515**(0.258)
21	**0.565****(0.012)	**0.517**(0.217)	**0.545***(0.064)	**0.551****(0.039)	**0.507**(0.429)
24	**0.561****(0.026)	**0.505**(0.432)	**0.547***(0.081)	**0.547***(0.084)	**0.529**(0.181)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

Table A-2b. Forecast Accuracy for WTI, Evaluation 1992:01 to 2017:12

	Real WTI price				
			Rolling weights based on windows of length		
MH	Equal weight	Recursive weights	36	24	12
			Recursive MSPE ratios		
1	**0.907****(0.002)	**0.910****(0.002)	**0.912****(0.003)	**0.912****(0.004)	**0.909****(0.004)
3	**0.923****(0.002)	**0.925****(0.002)	**0.929****(0.004)	**0.927****(0.003)	**0.927****(0.002)
6	**0.979***(0.079)	**0.984**(0.138)	**0.984**(0.131)	**0.984**(0.119)	**0.988**(0.208)
9	**0.973****(0.027)	**0.980***(0.082)	**0.974****(0.039)	**0.974****(0.043)	**0.979***(0.092)
12	**0.942****(0.000)	**0.950****(0.001)	**0.942****(0.000)	**0.931****(0.000)	**0.935****(0.000)
15	**0.937****(0.000)	**0.949****(0.001)	**0.944****(0.001)	**0.934****(0.000)	**0.917****(0.000)
18	**0.944****(0.000)	**0.963****(0.011)	**0.970***(0.056)	**0.972***(0.092)	**0.982**(0.248)
21	**0.970****(0.023)	**0.994**(0.340)	**0.991**(0.313)	**0.991**(0.340)	**0.987**(0.309)
24	**0.956****(0.005)	**0.995**(0.361)	**0.967****(0.035)	**0.964****(0.034)	**0.990**(0.377)
			Success ratios		
1	**0.558***(0.059)	**0.561***(0.052)	**0.545**(0.155)	**0.551**(0.109)	**0.574****(0.019)
3	**0.577****(0.012)	**0.565****(0.037)	**0.571****(0.021)	**0.571****(0.022)	**0.565****(0.044)
6	**0.544**(0.169)	**0.541**(0.213)	**0.541**(0.205)	**0.534**(0.235)	**0.521**(0.436)
9	**0.572****(0.011)	**0.572****(0.011)	**0.582****(0.005)	**0.572****(0.013)	**0.559****(0.030)
12	**0.618****(0.000)	**0.601****(0.000)	**0.608****(0.000)	**0.621****(0.000)	**0.598****(0.001)
15	**0.614****(0.000)	**0.594****(0.001)	**0.594****(0.001)	**0.607****(0.000)	**0.597****(0.001)
18	**0.593****(0.000)	**0.583****(0.001)	**0.573****(0.004)	**0.559****(0.019)	**0.563****(0.012)
21	**0.599****(0.000)	**0.534***(0.066)	**0.555****(0.022)	**0.558****(0.029)	**0.551****(0.048)
24	**0.554****(0.042)	0.488(0.642)	**0.547***(0.071)	**0.529**(0.195)	**0.536**(0.118)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

(III) The inclusion of futures-based forecasts

Analysing the effect of including the futures-based forecasts, in Table A-3a and A-3b we compare the the forecast accuracy of equal weight combinations with and without futures-based forecasts for the 1992:01-2012:09 and 1992:01-2017:12 sample periods at horizons 18 to 24 months for RAC and WTI. As with Brent in the main text, the inclusion of futures-based forecasts at these horizons reduces MSPE ratios and raises the success ratios. Table A-4 additionally presents the effect of including the futures-based forecasts for the Brent measure in the 1992:01-2012:09 evaluation sample.

Table A-3a: Forecast Accuracy for RAC, Equal Weight Combinations, Excluding and Including Futures-based Forecasts (FUTURES)

	Real RAC price			
	1992:01-2012:09		1992:01-2017:12	
MH	Excluding FUTURES	Including FUTURES	Excluding FUTURES	Including FUTURES
	Recursive MSPE ratios			
18	1.013(0.706)	**0.974***(0.073)	1.000(0.502)	**0.944****(0.000)
19	1.029(0.887)	**0.989**(0.269)	1.009(0.727)	**0.952****(0.001)
20	1.044(0.967)	1.004(0.586)	1.026(0.956)	**0.964****(0.008)
21	1.044(0.966)	1.006(0.636)	1.036(0.992)	**0.972****(0.022)
22	1.036(0.923)	1.000(0.505)	1.036(0.990)	**0.971****(0.020)
23	1.022(0.805)	**0.991**(0.293)	1.034(0.979)	**0.968****(0.015)
24	1.014(0.704)	**0.987**(0.224)	1.035(0.979)	**0.970****(0.024)
	Success ratios			
18	**0.522**(0.665)	**0.573****(0.001)	**0.508**(0.567)	**0.586****(0.001)
19	**0.524**(0.546)	**0.580****(0.000)	**0.537**(0.155)	**0.595****(0.000)
20	**0.557**(0.198)	**0.609****(0.000)	**0.546**(0.136)	**0.614****(0.000)
21	**0.502**(0.894)	**0.563****(0.006)	0.479(0.937)	**0.565****(0.012)
22	**0.518**(0.836)	**0.566****(0.009)	0.485(0.902)	**0.560****(0.021)
23	**0.546**(0.577)	**0.555****(0.026)	**0.507**(0.714)	**0.552****(0.044)
24	**0.540**(0.693)	**0.553****(0.048)	**0.509**(0.737)	**0.561****(0.026)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

Table A-3b: Forecast Accuracy for WTI, Equal Weight Combinations, Excluding and Including Futures-based Forecasts (FUTURES)

	Real WTI price			
	1992:01-2012:09		1992:01-2017:12	
MH	Excluding FUTURES	Including FUTURES	Excluding FUTURES	Including FUTURES
	Recursive MSPE ratios			
18	1.011(0.678)	**0.973***(0.070)	**0.999**(0.476)	**0.944****(0.000)
19	1.022(0.820)	**0.985**(0.206)	1.008(0.693)	**0.952****(0.001)
20	1.035(0.922)	**0.998**(0.466)	1.021(0.906)	**0.963****(0.007)
21	1.040(0.942)	1.004(0.599)	1.032(0.973)	**0.970****(0.023)
22	1.027(0.846)	**0.995**(0.398)	1.028(0.947)	**0.966****(0.013)
23	1.012(0.667)	**0.985**(0.210)	1.022(0.882)	**0.960****(0.007)
24	1.002(0.534)	**0.979**(0.146)	1.017(0.808)	**0.956****(0.005)
	Success ratios			
18	**0.526**(0.542)	**0.582****(0.001)	**0.522**(0.443)	**0.593****(0.000)
19	**0.528**(0.387)	**0.593****(0.000)	**0.534**(0.216)	**0.609****(0.000)
20	**0.535**(0.411)	**0.587****(0.000)	**0.539**(0.226)	**0.590****(0.000)
21	0.498(0.910)	**0.581****(0.003)	**0.503**(0.818)	**0.599****(0.000)
22	**0.526**(0.753)	**0.570****(0.007)	**0.509**(0.768)	**0.584****(0.002)
23	**0.529**(0.687)	**0.551****(0.048)	**0.514**(0.651)	**0.569****(0.012)
24	**0.531**(0.720)	**0.540**(0.108)	**0.505**(0.735)	**0.554****(0.042)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

Table A-4: Forecast Accuracy for Brent, Equal Weight Combinations, Excluding and Including Futures-based Forecasts (FUTURES)

	Real Brent price			
	1992:01-2012:09			
	Recursive MSPE ratios		**Success ratios**	
MH	Excluding FUTURES	Including FUTURES	Excluding FUTURES	Including FUTURES
9	**0.998**(0.468)	**0.983**(0.176)	0.490(0.644)	**0.506**(0.315)
10	**0.992**(0.365)	**0.975***(0.071)	**0.504**(0.491)	**0.537****(0.050)
11	**0.979**(0.188)	**0.961****(0.012)	**0.540**(0.148)	**0.573****(0.004)
12	**0.974**(0.131)	**0.952****(0.003)	**0.546***(0.087)	**0.567****(0.005)
13	**0.974**(0.130)	**0.949****(0.001)	**0.515**(0.384)	**0.578****(0.003)
14	**0.972**(0.120)	**0.945****(0.001)	**0.538**(0.169)	**0.568****(0.005)
15	**0.976**(0.154)	**0.947****(0.001)	**0.549***(0.075)	**0.583****(0.001)
16	**0.989**(0.323)	**0.957****(0.006)	**0.534**(0.142)	**0.577****(0.001)
17	1.008(0.631)	**0.973****(0.047)	**0.511**(0.280)	**0.536****(0.009)
18	1.023(0.837)	**0.986**(0.203)	**0.530***(0.067)	**0.543****(0.002)
19	1.036(0.941)	1.001(0.513)	**0.515***(0.093)	**0.524****(0.004)
20	1.048(0.983)	1.012(0.787)	**0.526***(0.099)	**0.522****(0.005)
21	1.054(0.991)	1.018(0.898)	**0.524**(0.203)	**0.528****(0.003)
22	1.051(0.984)	1.018(0.884)	**0.504**(0.477)	**0.531****(0.007)
23	1.043(0.958)	1.013(0.787)	**0.511**(0.386)	**0.515***(0.051)
24	1.041(0.945)	1.014(0.799)	0.491(0.672)	0.491(0.253)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

(IV) Activity Indexes

Hamilton (2018) proposes a 24-month cumulative growth rate of real shipping rates as an alternative measure of global activity. This series and the rea are plotted in Figure A-1, see the online dataset documentation for more details.

If we use Hamilton's 24-month cumulative growth rate of real shipping rates in the VAR, the forecast performance is fairly similar, and the influence on the forecast produced using the equal-weight combination is negligible. The results are presented in Tables A-5, A-6, and A-7 for the three real oil prices measures.

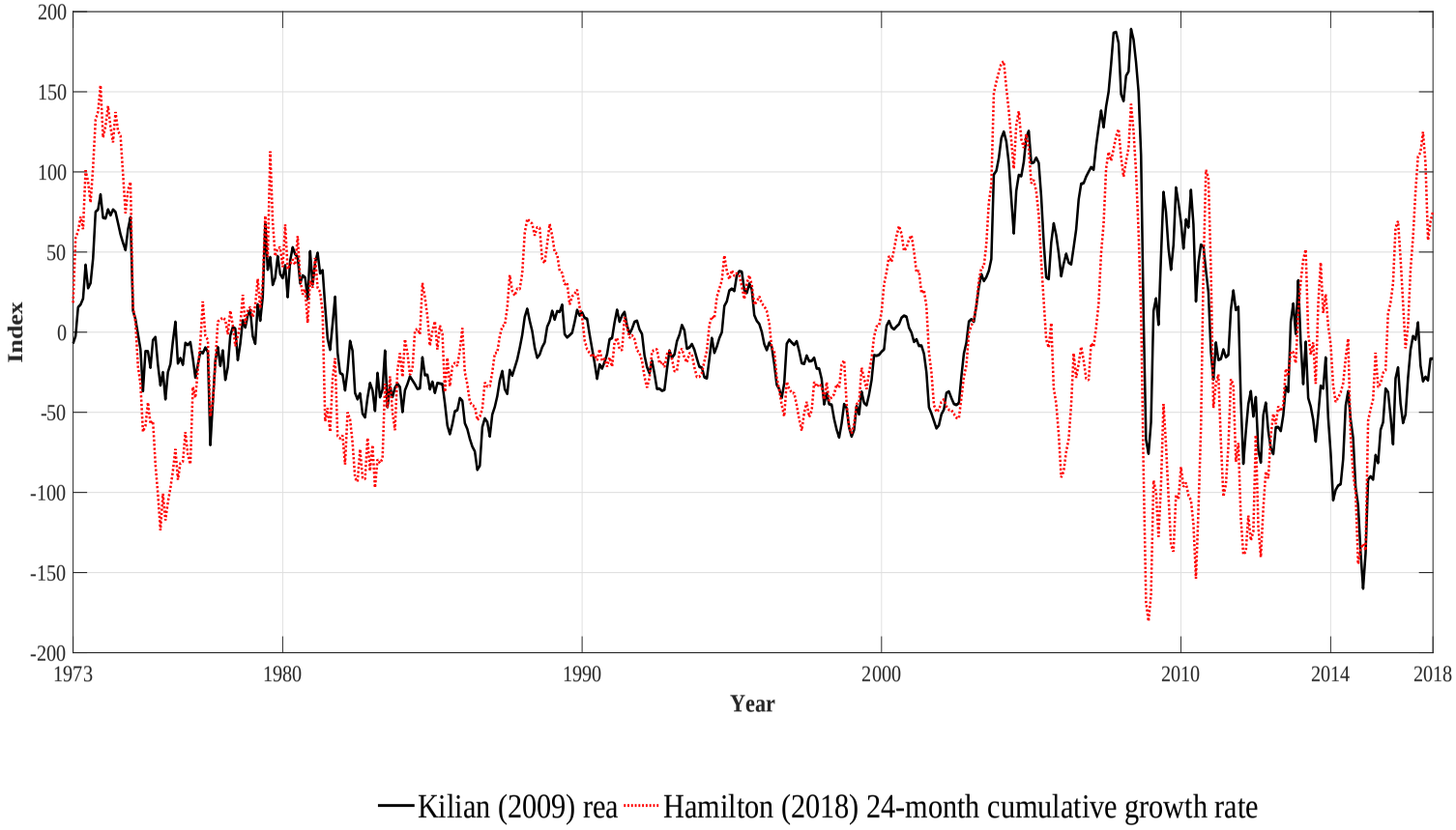

Figure A-1: Kilian (2009) rea and Hamilton (2018) 24-month cumulative activity growth rate

Table A-5: Forecast Accuracy for RAC, VAR & Equal Weight Combination, using Kilian (2009) rea and Hamilton (2018) 24-month cumulative activity growth rate

	Evaluation 1992:01 to 2012:09				**Evaluation 1992:01 to 2017:12**			
	VAR		**Equal Weight Combination**		**VAR**		**Equal Weight Combination**	
MH	Kilian	Hamilton	Kilian	Hamilton	Kilian	Hamilton	Kilian	Hamilton
				Recursive MSPE ratios				
1	**0.990**(0.465)	1.011(0.529)	**0.928****(0.028)	**0.921****(0.031)	**0.988**(0.452)	1.007(0.523)	**0.931****(0.015)	**0.925****(0.019)
3	1.051(0.678)	1.081(0.689)	**0.922****(0.008)	**0.911****(0.011)	1.014(0.558)	1.049(0.641)	**0.923****(0.002)	**0.916****(0.004)
6	1.186(0.988)	1.183(0.983)	**0.985**(0.172)	**0.982**(0.145)	1.105(0.926)	1.112(0.934)	**0.977****(0.048)	**0.978***(0.059)
9	1.232(1.000)	1.271(1.000)	**0.980**(0.111)	**0.986**(0.176)	1.119(0.986)	1.158(0.998)	**0.971****(0.015)	**0.978****(0.036)
12	1.231(1.000)	1.282(1.000)	**0.941****(0.001)	**0.947****(0.002)	1.089(0.953)	1.143(0.996)	**0.936****(0.000)	**0.944****(0.000)
15	1.257(1.000)	1.283(1.000)	**0.932****(0.000)	**0.935****(0.000)	1.074(0.894)	1.108(0.969)	**0.932****(0.000)	**0.938****(0.000)
18	1.322(1.000)	1.327(1.000)	**0.974***(0.073)	**0.974***(0.072)	1.062(0.829)	1.084(0.914)	**0.944****(0.000)	**0.949****(0.000)
21	1.369(1.000)	1.383(1.000)	1.006(0.636)	1.009(0.706)	1.044(0.735)	1.078(0.870)	**0.972****(0.022)	**0.978***(0.056)
24	1.385(1.000)	1.385(1.000)	**0.987**(0.224)	**0.987**(0.225)	1.034(0.675)	1.059(0.801)	**0.970****(0.024)	**0.975****(0.042)
				Success ratios				
1	**0.546***(0.083)	**0.558****(0.041)	**0.562****(0.050)	**0.566****(0.038)	**0.558****(0.022)	**0.564****(0.014)	**0.558****(0.042)	**0.567****(0.019)
3	**0.526**(0.214)	**0.522**(0.248)	**0.575****(0.034)	**0.583****(0.019)	**0.532**(0.113)	**0.526**(0.169)	**0.597****(0.002)	**0.606****(0.000)
6	0.475(0.743)	0.426(0.993)	**0.545**(0.201)	**0.566***(0.091)	0.495(0.500)	0.469(0.868)	**0.573****(0.021)	**0.590****(0.005)
9	0.444(0.949)	0.427(0.994)	**0.539**(0.171)	**0.523**(0.419)	0.480(0.700)	0.464(0.896)	**0.549***(0.068)	**0.543**(0.117)
12	**0.521**(0.167)	0.475(0.857)	**0.639****(0.000)	**0.634****(0.000)	**0.578****(0.001)	**0.538***(0.070)	**0.645****(0.000)	**0.638****(0.000)
15	**0.515**(0.261)	0.455(0.968)	**0.617****(0.000)	**0.591****(0.007)	**0.560****(0.006)	**0.510**(0.332)	**0.614****(0.000)	**0.594****(0.001)
18	**0.513**(0.315)	0.470(0.919)	**0.573****(0.001)	**0.565****(0.009)	**0.569****(0.004)	**0.539***(0.075)	**0.586****(0.001)	**0.569****(0.007)
21	**0.502**(0.533)	0.476(0.926)	**0.563****(0.006)	**0.546***(0.058)	**0.565****(0.005)	**0.551****(0.028)	**0.565****(0.012)	**0.551****(0.047)
24	0.500(0.649)	0.491(0.835)	**0.553****(0.048)	**0.544**(0.123)	**0.561****(0.011)	**0.547****(0.042)	**0.561****(0.026)	**0.554***(0.051)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

Table A-6: Forecast Accuracy for WTI, VAR & Equal Weight Combination, using Kilian (2009) rea and Hamilton (2018) 24-month cumulative activity growth rate

	Evaluation 1992:01 to 2012:09				**Evaluation 1992:01 to 2017:12**			
	VAR		**Equal Weight Combination**		**VAR**		**Equal Weight Combination**	
MH	Kilian	Hamilton	Kilian	Hamilton	Kilian	Hamilton	Kilian	Hamilton
				Recursive MSPE ratios				
1	1.009(0.533)	1.050(0.630)	**0.904****(0.007)	**0.898****(0.010)	1.001(0.506)	1.036(0.612)	**0.907****(0.002)	**0.903****(0.004)
3	1.041(0.640)	1.103(0.739)	**0.923****(0.010)	**0.916****(0.017)	1.011(0.547)	1.076(0.717)	**0.923****(0.002)	**0.920****(0.007)
6	1.141(0.955)	1.172(0.973)	**0.988**(0.242)	**0.990**(0.301)	1.075(0.846)	1.113(0.930)	**0.979***(0.079)	**0.984**(0.161)
9	1.177(0.999)	1.233(1.000)	**0.982**(0.146)	**0.991**(0.281)	1.094(0.963)	1.145(0.997)	**0.973****(0.027)	**0.982***(0.076)
12	1.176(0.997)	1.245(1.000)	**0.948****(0.004)	**0.957****(0.011)	1.075(0.922)	1.143(0.996)	**0.942****(0.000)	**0.952****(0.001)
15	1.192(0.995)	1.235(0.999)	**0.942****(0.002)	**0.948****(0.005)	1.054(0.813)	1.100(0.957)	**0.937****(0.000)	**0.944****(0.000)
18	1.242(0.998)	1.265(0.999)	**0.973***(0.070)	**0.977***(0.094)	1.041(0.728)	1.076(0.884)	**0.944****(0.000)	**0.951****(0.001)
21	1.280(0.998)	1.311(0.999)	1.004(0.599)	1.011(0.729)	1.029(0.653)	1.072(0.846)	**0.970****(0.023)	**0.979***(0.071)
24	1.301(0.997)	1.313(0.999)	**0.979**(0.146)	**0.982**(0.170)	1.026(0.630)	1.062(0.800)	**0.956****(0.005)	**0.963****(0.012)
				Success ratios				
1	**0.518**(0.329)	**0.506**(0.499)	**0.542**(0.201)	**0.530**(0.348)	**0.535**(0.115)	**0.522**(0.245)	**0.558***(0.059)	**0.558***(0.065)
3	**0.547***(0.076)	**0.518**(0.291)	**0.551**(0.158)	**0.530**(0.377)	**0.545****(0.047)	**0.519**(0.234)	**0.577****(0.012)	**0.558***(0.063)
6	0.484(0.653)	0.443(0.974)	**0.525**(0.425)	**0.553**(0.172)	0.498(0.450)	0.472(0.842)	**0.544**(0.169)	**0.573****(0.026)
9	0.477(0.722)	0.452(0.958)	**0.552***(0.082)	**0.523**(0.402)	0.487(0.607)	0.464(0.896)	**0.572****(0.011)	**0.553***(0.068)
12	0.496(0.468)	0.450(0.963)	**0.584****(0.005)	**0.563***(0.064)	**0.532***(0.065)	0.492(0.562)	**0.618****(0.000)	**0.605****(0.000)
15	**0.532**(0.128)	0.481(0.827)	**0.587****(0.004)	**0.579****(0.017)	**0.560****(0.006)	**0.510**(0.332)	**0.614****(0.000)	**0.607****(0.000)
18	**0.526**(0.190)	0.474(0.887)	**0.582****(0.001)	**0.560****(0.013)	**0.553****(0.014)	**0.508**(0.336)	**0.593****(0.000)	**0.569****(0.005)
21	**0.520**(0.317)	0.493(0.812)	**0.581****(0.003)	**0.568****(0.016)	**0.555****(0.010)	**0.541***(0.053)	**0.599****(0.000)	**0.579****(0.006)
24	0.496(0.685)	0.487(0.851)	**0.540**(0.108)	**0.531**(0.266)	**0.561****(0.012)	**0.547****(0.044)	**0.554****(0.042)	**0.547***(0.083)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

Table A-7: Forecast Accuracy for BRENT, VAR & Equal Weight Combination, using Kilian (2009) rea and Hamilton (2018) 24-month cumulative activity growth rate

	Evaluation 1992:01 to 2012:09				**Evaluation 1992:01 to 2017:12**			
	VAR		**Equal Weight Combination**		**VAR**		**Equal Weight Combination**	
MH	Kilian	Hamilton	Kilian	Hamilton	Kilian	Hamilton	Kilian	Hamilton
				Recursive MSPE ratios				
1	1.017(0.563)	1.083(0.720)	**0.956**(0.110)	**0.953**(0.122)	1.017(0.571)	1.077(0.742)	**0.941****(0.030)	**0.939****(0.039)
3	1.057(0.697)	1.138(0.802)	**0.941****(0.024)	**0.934****(0.031)	1.040(0.665)	1.123(0.823)	**0.935****(0.005)	**0.932****(0.010)
6	1.180(0.986)	1.205(0.989)	**0.995**(0.394)	**0.995**(0.397)	1.111(0.936)	1.144(0.969)	**0.978***(0.093)	**0.981**(0.118)
9	1.219(1.000)	1.261(1.000)	**0.983**(0.176)	**0.990**(0.255)	1.116(0.986)	1.159(0.999)	**0.961****(0.007)	**0.968****(0.011)
12	1.233(1.000)	1.287(1.000)	**0.952****(0.003)	**0.958****(0.005)	1.089(0.953)	1.150(0.997)	**0.929****(0.000)	**0.937****(0.000)
15	1.264(1.000)	1.297(1.000)	**0.947****(0.001)	**0.951****(0.001)	1.074(0.892)	1.118(0.979)	**0.923****(0.000)	**0.930****(0.000)
18	1.315(1.000)	1.326(1.000)	**0.986**(0.203)	**0.988**(0.216)	1.069(0.854)	1.096(0.942)	**0.937****(0.000)	**0.943****(0.000)
21	1.346(1.000)	1.362(1.000)	1.018(0.898)	1.022(0.940)	1.049(0.759)	1.084(0.897)	**0.955****(0.002)	**0.962****(0.004)
24	1.358(1.000)	1.359(1.000)	1.014(0.799)	1.014(0.822)	1.032(0.672)	1.061(0.817)	**0.950****(0.002)	**0.955****(0.002)
				Success ratios				
1	**0.502**(0.510)	0.498(0.575)	**0.514**(0.199)	**0.526***(0.094)	**0.513**(0.341)	**0.506**(0.446)	**0.526***(0.069)	**0.542****(0.017)
3	**0.510**(0.395)	0.498(0.539)	**0.538**(0.134)	**0.522**(0.263)	**0.516**(0.263)	**0.510**(0.352)	**0.561****(0.015)	**0.542***(0.070)
6	0.480(0.694)	0.439(0.983)	0.496(0.552)	0.480(0.743)	0.495(0.507)	0.469(0.867)	**0.534**(0.112)	**0.524**(0.203)
9	0.452(0.915)	0.436(0.989)	**0.506**(0.315)	0.481(0.602)	0.477(0.729)	0.467(0.874)	**0.569****(0.003)	**0.553****(0.015)
12	0.479(0.680)	0.433(0.989)	**0.567****(0.005)	**0.580****(0.002)	**0.538***(0.061)	**0.505**(0.404)	**0.605****(0.000)	**0.608****(0.000)
15	**0.506**(0.370)	0.447(0.978)	**0.583****(0.001)	**0.562****(0.011)	**0.560****(0.009)	**0.510**(0.344)	**0.621****(0.000)	**0.611****(0.000)
18	**0.509**(0.361)	0.466(0.945)	**0.543****(0.002)	**0.552****(0.001)	**0.576****(0.002)	**0.539***(0.073)	**0.586****(0.000)	**0.603****(0.000)
21	**0.502**(0.533)	0.485(0.879)	**0.528****(0.003)	**0.546****(0.000)	**0.572****(0.003)	**0.565****(0.009)	**0.558****(0.004)	**0.579****(0.000)
24	0.478(0.849)	0.469(0.945)	0.491(0.253)	0.491(0.253)	**0.554****(0.025)	**0.540***(0.076)	**0.540***(0.055)	**0.547****(0.031)

NOTES: MH represents monthly forecast horizons. Boldface indicates improvements relative to the no-change forecast. As a rough guide, p-values of a Harvey et al. (1997) small-sample adjustment of the Diebold and Mariano (1995) test are reported in brackets after recursive MSPE ratios. We also report p-values for the Pesaran and Timmermann (2009) test for the null hypothesis of no directional accuracy in brackets after success ratios. $*$ denotes significance at the 10% level and $**$ at the 5% level.

References

Baumeister, C., & Kilian, L. (2015). Forecasting the real price of oil in a changing world: A forecast combination approach. *Journal of Business & Economic Statistics*, *33*(3), 338–351. doi: 10.1080/07350015.2014.949342

Diebold, F. X., & Mariano, R. S. (1995). Comparing predictive accuracy. *Journal of Business & Economic Statistics*, *13*(3), 253–263. doi: 10.2307/1392185

Hamilton, J. D. (2018). Measuring global economic activity. *Working Paper*. Retrieved from `http://econweb.ucsd.edu/~jhamilto/REA.pdf`

Harvey, D., Leybourne, S., & Newbold, P. (1997). Testing the equality of prediction mean squared errors. *International Journal of forecasting*, *13*(2), 281–291. doi: 10.1016/S0169-2070(96)00719-4

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *The American Economic Review*, *99*(3), 1053–1069. doi: 10.1257/aer.99.3.1053

Pesaran, M. H., & Timmermann, A. (2009). Testing dependence among serially correlated multicategory variables. *Journal of the American Statistical Association*, *104*(485), 325–337. Retrieved from `http://www.jstor.org/stable/40591921`