

Online Appendices (1/3)

Co-movements and spillovers of oil and renewable firms under extreme conditions: New evidence from negative WTI prices during COVID-19

Abstract

We test for the existence of volatility spillovers and co-movements among energy-focused corporations during the outbreak of the COVID-19 pandemic, inclusive of the April 2020 events where West Texas Intermediate (WTI) oil future prices became negative. Employing the spillover index approach; as well as developing a DCC-FIGARCH conditional correlation framework and using estimated spillover indices built on a generalised vector autoregressive framework in which forecast-error variance decompositions are invariant to the variable ordering, we examine the sectoral transmission mechanisms of volatility shocks and contagion throughout the energy sector. Among several results, we find positive and economically meaningful spillovers from falling oil prices to both renewable energy and coal markets. However, this result is only found for the narrow portion of our sample surrounding the negative WTI event. We interpret our results being directly attributed to a sharp drop in global oil, gas and coal demand, rather than because of a sudden increase in oil supply. While investors observed the US fracking industry losing market share to coal, they also viewed renewables as more reliable mechanism to generate long-term, stable and low-cost supply.

Keywords: Oil prices; Oil and gas corporations; Volatility spillovers; Volatility co-movement; Market linkage; Financial crisis; Contagion.

Table A1. List of Companies by Sector used in the above analysis

A. Oil & Gas Exploration & Production				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
ConocoPhillips	COP	US20825C1045	20825C104	Oil & Gas Exploration and Production (NEC)
EOG Resources Inc	EOG	US26875P1012	26875P101	Oil & Gas Exploration and Production (NEC)
Occidental Petroleum Corp	OXY	US6745991058	674599105	Oil & Gas Exploration and Production (NEC)
Pioneer Natural Resources Co	PXD	US7237871071	723787107	Oil & Gas Exploration and Production (NEC)
Concho Resources Inc	CXO	US20605P1012	20605P101	Oil & Gas Exploration and Production (NEC)
Cabot Oil & Gas Corp	COG	US1270971039	127097103	Oil & Gas Exploration and Production (NEC)
Continental Resources Inc	CLR	US2120151012	212015101	Oil & Gas Exploration and Production (NEC)
Apache Corp	APA	US0374111054	37411105	Oil & Gas Exploration and Production (NEC)
Marathon Oil Corp	MRO	US5658491064	565849106	Oil & Gas Exploration and Production (NEC)
Devon Energy Corp	DVN	US25179M1036	25179M103	Oil & Gas Exploration and Production (NEC)
Texas Pacific Land Trust	TPL	US8826101086	882610108	Oil & Gas Exploration and Production (NEC)
Parsley Energy Inc	PE	US7018771029	701877102	Oil & Gas Exploration and Production (NEC)
EQT Corp	EQT	US26884L1098	26884L109	Oil & Gas Exploration and Production (NEC)
WPX Energy Inc	WPX	US98212B1035	98212B103	Oil & Gas Exploration and Production (NEC)
Cimarex Energy Co	XEC	US1717981013	171798101	Oil & Gas Exploration and Production (NEC)
CNX Resources Corp	CNX	US12653C1080	12653C108	Oil & Gas Exploration and Production (NEC)
Murphy Oil Corp	MUR	US6267171022	626717102	Oil & Gas Exploration and Production (NEC)
Southwestern Energy Co	SWN	US8454671095	845467109	Oil & Gas Exploration and Production (NEC)
B. Oil & Gas Refining & Marketing				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
Exxon Mobil Corp	XOM	US30231G1022	30231G102	Oil & Gas Refining and Marketing (NEC)
Chevron Corp	CVX	US1667641005	166764100	Petroleum Refining
Phillips 66	PSX	US7185461040	718546104	Oil & Gas Refining and Marketing (NEC)
Valero Energy Corp	VLO	US91913Y1001	91913Y100	Oil & Gas Refining and Marketing (NEC)
Marathon Petroleum Corp	MPC	US56585A1025	56585A102	Oil & Gas Refining and Marketing (NEC)
Hess Corp	HES	US42809H1077	42809H107	Oil & Gas Refining and Marketing (NEC)
HollyFrontier Corp	HFC	US4361061082	436106108	Petroleum Refining
Murphy Usa Inc	MUSA.K	US6267551025	626755102	Gasoline Stations
CVR Energy Inc	CVI	US12662P1084	12662P108	Petroleum Refining
Delek US Holdings Inc	DK	US24665A1034	24665A103	Petroleum Refining
World Fuel Services Corp	INT	US9814751064	981475106	Petroleum Product Wholesale
PBF Energy Inc	PBF	US69318G1067	69318G106	Oil & Gas Refining and Marketing (NEC)
Par Pacific Holdings Inc	PARR.K	US69888T2078	69888T207	Oil & Gas Refining and Marketing (NEC)
C. Integrated Oil & Gas				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
QEP Resources Inc	QEP	US74733V1008	74733V100	Integrated Oil & Gas
Mistras Group Inc	MG	US60649T1079	60649T107	Integrated Oil & Gas
D. Oil-related Service & Equipment				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
Schlumberger NV	SLB	AN8068571086	806857108	Oil Related Services and Equipment (NEC)
Baker Hughes Co	BKR	US05722G1004	05722G100	Oil Related Services and Equipment (NEC)
Halliburton Co	HAL	US4062161017	406216101	Oil Related Services and Equipment (NEC)
National Oilwell Varco Inc	NOV	US6370711011	637071101	Oil Related Services and Equipment (NEC)
Antero Midstream Corp	AM	US03676B1026	03676B102	Oil Related Services and Equipment (NEC)
Cactus Inc	WHD	US1272031071	127203107	Oil Related Services and Equipment (NEC)
Dril-Quip Inc	DRQ	US2620371045	262037104	Oil Related Equipment
Archrock Inc	AROC.K	US03957W1062	03957W106	Oil Related Services and Equipment (NEC)
RPC Inc	RES	US7496601060	749660106	Oil Related Services and Equipment (NEC)
Apergy Corp	APY	US03755L1044	03755L104	Oil Related Equipment
SEACOR Holdings Inc	CKH	US8119041015	811904101	Oil Related Services
Liberty Oilfield Services Inc	LBRT.K	US53115L1044	53115L104	Oil Related Services
Oceanenergy International Inc	OII	US6752321025	675232102	Oil Related Services and Equipment (NEC)
Select Energy Services Inc	WTTR.K	US81617J3014	81617J301	Oil Related Services
Nextier Oilfield Solutions Inc	NEX	US65290C1053	65290C105	Oil Related Services

Note: Data was obtained from Thomson Reuters Eikon.

Table A1. List of Companies by Sector used in the above analysis (continued)

<i>E. Oil & Gas Transportation Services</i>				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
Kinder Morgan Inc	KMI	US49456B1017	49456B101	Oil & Gas Transportation Services (NEC)
Williams Companies Inc	WMB	US9694571004	969457100	Oil & Gas Transportation Services (NEC)
ONEOK Inc	OKE	US6826801036	682680103	Oil & Gas Transportation Services (NEC)
Hess Midstream Operations LP	HESM.K	US4281031058	428103105	Oil & Gas Transportation Services (NEC)
Targa Resources Corp	TRGP.K	US87612G1013	87612G101	Oil & Gas Transportation Services (NEC)
Plains GP Holdings LP	PAGP.K	US72651A2078	72651A207	Oil & Gas Transportation Services (NEC)
Equitrans Midstream Corp	ETR.N.K	US2946001011	294600101	Natural Gas Pipeline Transportation
International Seaways Inc	INSW.K	MHY410531021	Y41053102	Sea-Borne Tankers
Dorian LPG Ltd	LPG	MHY2106R1100	Y2106R110	Sea-Borne Tankers
Diamond S Shipping Inc	DSSI.K	MHY206761055	Y20676105	Sea-Borne Tankers
Overseas Shipholding Group Inc	OSG	US69036R8631	69036R863	Sea-Borne Tankers
SEACOR Marine Holdings Inc	SMHI.K	US78413P1012	78413P101	Sea-Borne Tankers
<i>F. Oil & Gas Drilling</i>				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
Helmerich and Payne Inc	HP	US4234521015	423452101	Oil & Gas Drilling (NEC)
Independence Contract Drilling Inc	ICD	US4534156066	453415606	Oil & Gas Drilling (NEC)
<i>G. Coal</i>				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
Arch Coal Inc	ARCH.K	US0393804077	39380407	Coal (NEC)
Peabody Energy Corp	BTU	US7045511000	704551100	Coal (NEC)
NACCO Industries Inc	NC	US6295791031	629579103	Coal (NEC)
CONSOL Energy Inc	CEIX.K	US20854L1089	20854L108	Coal (NEC)
Contura Energy Inc	CTRA.K	US21241B1008	21241B100	Coal (NEC)
<i>H. Renewable Energy</i>				
Name (or Code)	RIC	ISIN	CUSIP/CINS	TRBC Sector
Sunnova Energy International Inc	NOVA.K	US86745K1043	86745K104	Photovoltaic Solar Systems & Equipment
Ameresco Inc	AMRC.K	US02361E1082	2.36E+111	Renewable Energy Services
Vivint Solar Inc	VSLR.K	US92854Q1067	92854Q106	Photovoltaic Solar Systems & Equipment
FutureFuel Corp	FF	US36116M1062	36116M106	Biodiesel
REX American Resources Corp	REX	US7616241052	761624105	Ethanol Fuels

Note: Data was obtained from Thomson Reuters Eikon.

Table A2. Hurst Exponents by Company & Sector, Absolute Returns

a) Oil & Gas Exploration																	
a)	COP	EOG	OXY	PXD	CXO	COG	CLR	APA	MRO	DVN	TPL	PE	WPX	XEC	MUR		
Higuchi	0.81	0.86	0.8	0.86	0.88	0.87	0.84	0.83	0.85	0.83	0.87	0.86	0.82	0.84	0.84		
	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02		
Peng	0.67	0.55	0.51	0.58	0.7	0.59	0.57	0.46	0.53	0.6	0.64	0.59	0.59	0.65	0.65		
	0.08	0.09	0.1	0.1	0.05	0.06	0.09	0.09	0.09	0.09	0.07	0.08	0.11	0.08	0.08		
R/S	0.52	0.61	0.48	0.64	0.36	0.56	0.46	0.52	0.49	0.37	0.38	0.57	0.33	0.5	0.51		
	0.03	0.03	0.05	0.03	0.07	0.03	0.04	0.05	0.03	0.06	0.05	0.04	0.06	0.03	0.03		
Boxed P.	0.5	0.62	0.72	0.81	0.64	0.71	0.71	0.73	0.69	0.63	0.67	0.72	0.88	0.61	0.77		
	0.1	0.08	0.05	0.06	0.07	0.08	0.06	0.05	0.05	0.07	0.08	0.06	0.05	0.07	0.06		
b) Oil & Gas Refining & Marketing																	
b)	XOM	CVX	PSX	VLO	MPC	HES	HFC	MUSA	CVI	DK	INT	PBF	PARR				
Higuchi	0.81	0.77	0.8	0.83	0.83	0.84	0.85	0.85	0.82	0.86	0.84	0.83	0.76				
	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01				
Peng	0.78	0.63	0.66	0.66	0.65	0.53	0.64	0.64	0.65	0.67	0.7	0.57	0.58				
	0.08	0.1	0.09	0.08	0.08	0.08	0.07	0.05	0.07	0.07	0.07	0.1	0.11				
R/S	0.45	0.59	0.54	0.56	0.54	0.57	0.41	0.42	0.45	0.46	0.35	0.44	0.75				
	0.05	0.03	0.03	0.04	0.03	0.03	0.05	0.04	0.04	0.06	0.07	0.05	0.03				
Boxed P.	0.71	0.64	0.73	0.65	0.69	0.68	0.58	0.7	0.75	0.49	0.7	0.79	0.79				
	0.08	0.09	0.09	0.1	0.08	0.06	0.09	0.07	0.07	0.08	0.08	0.07	0.07				
c) & d) Integrated Oil & Gas, & Oil & Gas Transportation Services																	
c)	QEP	MG	d)			KMI	WMB	OKE	HESM	TRGP	PAGP	ETRN	INSW	LPG	OSG	SMHI	
Higuchi	0.83	0.79				0.75	0.77	0.7	0.72	0.78	0.74	0.85	0.86	0.9	0.89	0.83	
	0.02	0.01				0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	
Peng	0.53	0.67				0.68	0.65	0.53	0.59	0.53	0.6	0.64	0.64	0.68	0.62	0.69	
	0.08	0.06				0.1	0.11	0.12	0.1	0.12	0.13	0.04	0.06	0.05	0.05	0.07	
R/S	0.57	0.61				0.63	0.54	0.61	0.54	0.52	0.64	0.73	0.55	0.52	0.55	0.7	
	0.01	0.02				0.04	0.05	0.03	0.05	0.06	0.03	0.02	0.03	0.04	0.04	0.03	
Boxed P.	0.75	0.73				0.84	1.04	0.74	0.76	0.76	0.93	0.68	0.63	0.66	0.7	0.52	
	0.06	0.07				0.08	0.07	0.07	0.07	0.07	0.08	0.07	0.08	0.08	0.07	0.11	
e) Oil & Gas Services & Equipment																	
e)	SLB	BKR	HAL	NOV	AM	WHD	DRQ	AROC	RES	APY	CKH	LBRT	OII	WTTR	NEX		
Higuchi	0.84	0.86	0.83	0.86	0.87	0.84	0.9	0.83	0.89	0.79	0.85	0.87	0.84	0.84	0.86		
	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02		
Peng	0.68	0.7	0.62	0.73	0.56	0.52	0.66	0.46	0.49	0.47	0.75	0.53	0.57	0.57	0.6		
	0.08	0.09	0.09	0.07	0.03	0.08	0.05	0.09	0.04	0.1	0.08	0.07	0.08	0.08	0.06		
R/S	0.35	0.5	0.52	0.37	0.65	0.78	0.43	0.53	0.45	0.56	0.58	0.7	0.35	0.65	0.53		
	0.05	0.05	0.03	0.06	0.02	0.06	0.05	0.05	0.06	0.02	0.02	0.02	0.07	0.04	0.04		
Boxed P.	0.63	0.77	0.65	0.78	0.55	0.48	0.74	0.69	0.53	0.38	0.83	0.56	0.63	0.46	0.64		
	0.08	0.08	0.07	0.07	0.07	0.09	0.07	0.06	0.08	0.1	0.07	0.07	0.07	0.1	0.06		
f), g) and h) Oil & Gas Drilling, Coal & Renewable Energy respectively																	
f)	HP	ICD	g)			ARCH	BTU	NC	CEIX	CTRA	h)			AMRC	VSLR	FF	REX
Higuchi	0.83	0.82				0.84	0.83	0.87	0.8	0.8				0.82	0.89	0.93	0.84
	0.02	0.01				0.02	0.01	0.02	0.01	0.01				0.02	0.02	0.03	0.02
Peng	0.65	0.48				0.61	0.61	0.65	0.55	0.64				0.6	0.65	0.57	0.53
	0.08	0.08				0.05	0.06	0.05	0.07	0.06				0.06	0.05	0.03	0.1
R/S	0.67	0.7				0.5	0.52	0.8	0.43	0.67				0.54	0.69	0.46	0.69
	0.02	0.03				0.04	0.04	0.04	0.05	0.04				0.04	0.03	0.06	0.03
Boxed P.	0.78	0.87				0.61	0.75	0.59	0.66	0.78				0.66	0.78	0.57	0.76
	0.06	0.06				0.08	0.07	0.08	0.08	0.06				0.07	0.08	0.07	0.07

Note: The above data represents hourly sectoral price volatility for the period March 2019 through May 2020. Data was obtained from Thomson Reuters Eikon. All of the test statistics are significant at 95% confidence level

Table A3. Hurst Exponents by Company & Sector, Squared Returns

a) Oil & Gas Exploration															
a)	COP	EOG	OXY	PXD	CXO	COG	CLR	APA	MRO	DVN	TPL	PE	WPX	XEC	MUR
Higuchi	0.48	0.61	0.37	0.59	0.79	0.73	0.57	0.49	0.55	0.56	0.64	0.60	0.47	0.60	0.56
	0.07	0.05	0.11	0.06	0.03	0.03	0.07	0.08	0.07	0.06	0.04	0.05	0.08	0.05	0.06
Peng	0.31	0.21	0.00	0.22	0.63	0.54	0.24	0.22	0.14	0.26	0.37	0.31	0.25	0.33	0.37
	0.15	0.19	0.27	0.20	0.04	0.08	0.19	0.17	0.23	0.18	0.13	0.16	0.20	0.16	0.17
R/S	0.54	0.62	0.48	0.61	0.46	0.51	0.47	0.62	0.46	0.42	0.41	0.52	0.34	0.54	0.59
	0.02	0.02	0.04	0.03	0.05	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.06	0.02	0.03
Boxed Per.	0.50	0.60	0.56	0.67	0.61	0.75	0.59	0.60	0.56	0.58	0.55	0.64	0.70	0.60	0.63
	0.10	0.06	0.05	0.06	0.07	0.09	0.05	0.05	0.05	0.06	0.10	0.06	0.07	0.06	0.06
b) Oil & Gas Refining & Marketing															
b)	XOM	CVX	PSX	VLO	MPC	HES	HFC	MUSA	CVI	DK	INT	PBF	PARR		
Higuchi	0.52	0.33	0.47	0.54	0.52	0.59	0.60	0.69	0.50	0.62	0.59	0.51	0.33		
	0.06	0.11	0.07	0.06	0.06	0.06	0.04	0.04	0.07	0.04	0.04	0.06	0.10		
Peng	0.52	0.18	0.38	0.38	0.30	0.22	0.45	0.55	0.41	0.37	0.45	0.28	0.12		
	0.12	0.18	0.16	0.13	0.15	0.17	0.11	0.04	0.15	0.13	0.11	0.18	0.21		
R/S	0.51	0.50	0.55	0.58	0.50	0.59	0.53	0.47	0.51	0.47	0.38	0.49	0.86		
	0.03	0.04	0.03	0.03	0.04	0.02	0.04	0.04	0.02	0.05	0.07	0.05	0.05		
Boxed Per.	0.56	0.71	0.95	0.79	0.74	0.61	0.39	0.54	0.81	0.45	0.55	0.90	0.72		
	0.11	0.10	0.08	0.08	0.08	0.06	0.11	0.08	0.07	0.09	0.09	0.06	0.07		
c) & d) Integrated Oil & Gas, & Oil & Gas Transportation Services															
c)	QEP	MG	d)		KMI	WMB	OKE	HESM	TRGP	PAGP	ETRN	INSW	LPG	OSG	SMHI
c) Higuchi	0.54	0.58			0.30	0.35	0.15	0.22	0.32	0.23	0.63	0.68	0.77	0.75	0.57
	0.06	0.04			0.11	0.11	0.16	0.13	0.12	0.13	0.04	0.03	0.03	0.02	0.05
Peng	0.27	0.53			0.21	0.26	0.05	0.12	0.04	0.12	0.45	0.51	0.54	0.56	0.53
	0.16	0.08			0.20	0.19	0.24	0.22	0.24	0.24	0.10	0.09	0.08	0.08	0.10
R/S	0.53	0.57			0.57	0.57	0.60	0.56	0.55	0.64	0.61	0.63	0.53	0.53	0.69
	0.02	0.02			0.05	0.04	0.02	0.05	0.05	0.03	0.02	0.02	0.02	0.04	0.02
Boxed Per.	0.65	0.62			0.81	1.03	0.62	0.62	0.56	0.75	0.76	0.80	0.66	0.69	0.50
	0.05	0.09			0.08	0.08	0.09	0.07	0.06	0.08	0.08	0.08	0.08	0.08	0.11
e) Oil & Gas Services & Equipment															
e)	SLB	BKR	HAL	NOV	AM	WHD	DRQ	AROC	RES	APY	CKH	LBRT	OII	WTTR	NEX
Higuchi	0.57	0.62	0.52	0.65	0.72	0.52	0.80	0.39	0.79	0.39	0.63	0.68	0.55	0.56	0.67
	0.06	0.05	0.07	0.04	0.02	0.06	0.02	0.10	0.02	0.09	0.04	0.02	0.06	0.05	0.03
Peng	0.37	0.45	0.23	0.50	0.35	0.19	0.64	-0.12	0.43	0.11	0.59	0.36	0.33	0.22	0.43
	0.15	0.14	0.17	0.13	0.08	0.18	0.06	0.21	0.07	0.19	0.14	0.10	0.13	0.14	0.10
R/S	0.42	0.54	0.53	0.37	0.60	0.74	0.45	0.49	0.44	0.50	0.55	0.59	0.42	0.56	0.63
	0.04	0.03	0.03	0.06	0.01	0.04	0.04	0.04	0.07	0.02	0.03	0.03	0.06	0.03	0.03
Boxed Per.	0.62	0.77	0.57	0.75	0.58	0.49	0.81	0.74	0.46	0.45	0.88	0.58	0.57	0.53	0.61
	0.07	0.08	0.06	0.07	0.08	0.08	0.09	0.06	0.09	0.08	0.10	0.08	0.07	0.09	0.06
f), g) and h) Oil & Gas Drilling, Coal & Renewable Energy respectively															
f)	HP	ICD	g)		ARCH	BTU	NC	CEIX	CTRA	h)		AMRC	VSLR	FF	REX
Higuchi	0.53	0.42			0.66	0.63	0.76	0.46	0.66			0.66	0.79	0.94	0.47
	0.06	0.08			0.03	0.04	0.02	0.07	0.05			0.03	0.03	0.04	0.08
Peng	0.38	0.07			0.41	0.56	0.56	0.30	0.55			0.41	0.55	0.51	0.09
	0.14	0.16			0.09	0.08	0.04	0.13	0.12			0.09	0.08	0.02	0.20
R/S	0.69	0.64			0.51	0.47	0.66	0.50	0.60			0.51	0.60	0.42	0.64
	0.01	0.02			0.03	0.04	0.03	0.04	0.03			0.03	0.03	0.06	0.03
Boxed Per.	0.67	0.79			0.63	0.84	0.42	0.70	0.53			0.63	0.87	0.52	0.75
	0.07	0.06			0.09	0.07	0.10	0.09	0.06			0.09	0.08	0.09	0.07

Note: The above data represents hourly sectoral price volatility for the period March 2019 through May 2020. Data was obtained from Thomson Reuters Eikon. All of the test statistics are significant at 95% confidence level

Table A4. Unit Root Test Results: ADF and PP Tests

Tests		CLc1	COP	EOG	OXY	PXD	CXO	COG	CLR	APA	MRO	DVN	TPL	PE	WPX
Log returns	ADF	-5.47	-4.84	-6.17	-5.69	-5.51	-5.8	-6.21	-6.07	-5.81	-5.25	-4.8	-5.04	-5.1	-4.59
	PP	-260.02	-450.69	-368.03	-356.31	-417.92	-368.93	-328.1	-356.9	-330.92	-358.94	-334.89	-423.15	-364.31	-393.23
Absolute returns	ADF	-2.52	-3.24	-5.18	-4.92	-5.52	-4.57	-4.16	-4.34	-4.97	-4.81	-3.67	-3.72	-4.4	-3.6
	PP	-231.77	-354.97	-295.12	-253.77	-234.9	-288.89	-339.81	-225.62	-297.46	-225.52	-275.84	-228	-266.5	-187.09
Squared returns	ADF	-2.77	-3.4	-6.07	-6.45	-6.04	-4.81	-3.78	-6.19	-5.74	-6.5	-4.72	-4.26	-5.24	-4.12
	PP	-294.23	-402.23	-324.63	-327.2	-284.72	-302.83	-389.88	-276.3	-344.19	-293.38	-308.22	-286.41	-303.34	-284.47
Tests		XOM	CVX	PSX	VLO	MPC	HES	HFC	MUSA	CVI	DK	INT	PBF	PARR	QEP
Log returns	ADF	-5.17	-5.72	-5.88	-5.95	-5.96	-6.33	-5.51	-6.58	-6.61	-6.04	-7.75	-5.55	-4.92	-4.68
	PP	-432.11	-473.54	-386.58	-360.49	-413.84	-388.57	-362.97	-394.15	-415.36	-357.96	-448.97	-395.15	-377.81	-323.22
Absolute returns	ADF	-2.97	-2.39	-3.21	-3.09	-3.2	-5.79	-3.5	-5.78	-3.4	-3.49	-2.89	-3.69	-4.31	-377.81
	PP	-277.5	-354.39	-203.41	-248.42	-404.66	-248.76	-321.79	-14.62	-226.91	-332.8	-302.36	-178.71	-14.81	-248.6
Squared returns	ADF	-3.11	-2.65	-3.67	-3.36	-4.2	-6.58	-3.81	-5.71	-5.12	-4.64	-2.89	-5.12	-5.15	-5.01
	PP	-405.19	-444.66	-150.77	-293.55	-443.58	-268.5	-355.31	-326.7	-186.37	-359.19	-371.3	-122.48	-379.87	-316.3
Tests		HAL	NOV	AM	WHD	DRQ	AROC.K	RES	APY	CKH	LBRT.K	OII	WTTR.K	NEX	KMI
Log returns	ADF	-4.47	-6.27	-4.68	-6.03	-8.13	-5.51	-7.2	-5.38	-6.89	-5.91	-6.6	-6.51	-5.66	-5.84
	PP	-390.33	-440.68	-288.58	-371.53	-334.3	-435.52	-286.11	-298.83	-379.16	-368.13	-347.06	-368.2	-371.47	-440.12
Absolute returns	ADF	-3.24	-4.52	-5.43	-4.1	-4.38	-4.05	-6.59	-2.94	-3.14	-4.01	-3.94	-3.04	-5.15	-3.16
	PP	-364.12	-269.61	-284.41	-292.52	-273.86	-194.64	-306	-283.1	-289.58	-343.14	-382.79	-286.09	-336.61	-286.35
Squared returns	ADF	-4.11	-5.22	-4.71	-5.46	-4.88	-5.04	-6.71	-4.05	-3.85	-3.15	-4.82	-3.43	-6.29	-3.5
	PP	-377.43	-316.28	-269.55	-302.17	-269.69	-165.67	-276.55	-320.74	-369.15	-344.68	-406.87	-255.49	-362.97	-382.83

Note: Data was obtained from Thomson Reuters Eikon.

Table A5. Unit Root Test with Multiple Structural Breaks: Kapetanios (2005) Test

a. Absolute Returns													
	Cic1	COP	XOM	CVX	PSX	VLO	MPC	CVI	INT	MG	SLB	BKR	
t stat	-16.1515	-20.7258	-10.8656	-9.461	-13.1969	-11.7074	-12.0913	-10.2493	-13.7037	-10.1561	-16.6522	-15.675	
Break Dates	05/21/19 09/18/19 03/05/20 03/20/20 04/09/20	07/24/19 09/17/19 12/09/2019 03/06/2020 04/16/20	07/31/19 01/30/20 02/21/20 03/25/20 04/14/20	02/04/2019 06/07/2019 12/17/2019 02/10/2020 03/06/2020	01/30/20 02/20/20 03/06/2020 03/26/20 04/14/20	01/30/20 02/20/20 03/06/2020 03/26/20 04/14/20	11/04/2019 01/30/20 02/21/20 03/10/2020 04/15/20	05/07/2019 08/01/2019 02/07/2020 03/06/2020 03/26/20	04/23/19 05/22/19 07/24/19 12/17/19 03/06/2020	07/25/19 10/09/2019 11/07/2019 02/21/20 04/01/2020	11/01/2019 03/19/20 03/03/2020 11/18/19 04/09/2020	06/24/19 07/31/19 02/20/20 03/06/2020 04/16/20	10/08/2019 12/23/19 02/10/2020 03/06/2020 04/16/20
	HAL	APY	CKH	WTTR	KMI	OKE	HESM	TRGP	LPG	SMHI	HP	ARCH	
t stat	-12.8991	-21.6845	-22.3074	-14.064	-17.9327	-14.075	-16.6506	-15.689	-11.3513	-15.1394	-19.4168	-11.3754	
Break Dates	07/16/19 12/17/19 02/12/20 03/05/20 04/09/20	11/05/2019 12/26/19 02/20/20 03/06/2020 04/14/20	11/04/2019 02/11/2020 03/04/2020 03/19/20 04/06/2020	04/29/19 02/11/2020 03/06/2020 03/30/20 04/15/20	04/17/19 01/22/20 02/12/2020 03/06/2020 03/25/20	04/17/19 09/03/2019 02/14/20 03/05/2020 03/20/20	07/30/19 07/29/19 11/08/2019 03/06/2020 04/02/2020	01/24/19 02/19/20 03/06/2020 03/06/2020 04/15/20	09/24/19 06/19/19 09/04/2019 03/06/2020 04/16/20	05/22/19 04/18/19 09/27/19 03/02/2020 03/17/20	01/28/19 02/10/2020 03/03/2020 03/18/20 04/08/2020	02/13/19 11/12/2019 01/13/20 03/06/2020 03/27/20	
b. Squared Returns													
	Cic1	COP	XOM	CVX	PSX	VLO	INT	LBRT	SMHI	ARCH			
t stat	-17.3662	-33.763	-19.8078	-9.448	-14.9214	-29.4751	-15.4428	-14.1563	-14.5567	-9.3443			
Break Dates	08/14/19 09/25/19 03/05/20 03/26/20 04/14/20	08/01/2019 02/20/20 03/06/2020 03/27/20 04/16/20	02/05/2019 08/29/19 09/25/19 03/06/2020 03/25/20	12/20/19 02/13/20 03/06/2020 03/26/20 04/16/20	04/23/19 01/30/20 02/20/20 03/06/2020 04/14/20	01/30/20 02/21/20 02/20/20 03/26/20 04/15/20	03/01/2019 04/22/19 03/11/2020 03/06/2020 04/01/2020	06/11/2019 08/30/19 12/30/19 03/04/2020 04/16/20	01/31/19 09/09/2019 09/19/19 03/23/20 04/16/20	07/31/19 08/15/19 11/12/2019 03/06/2020 04/15/20			

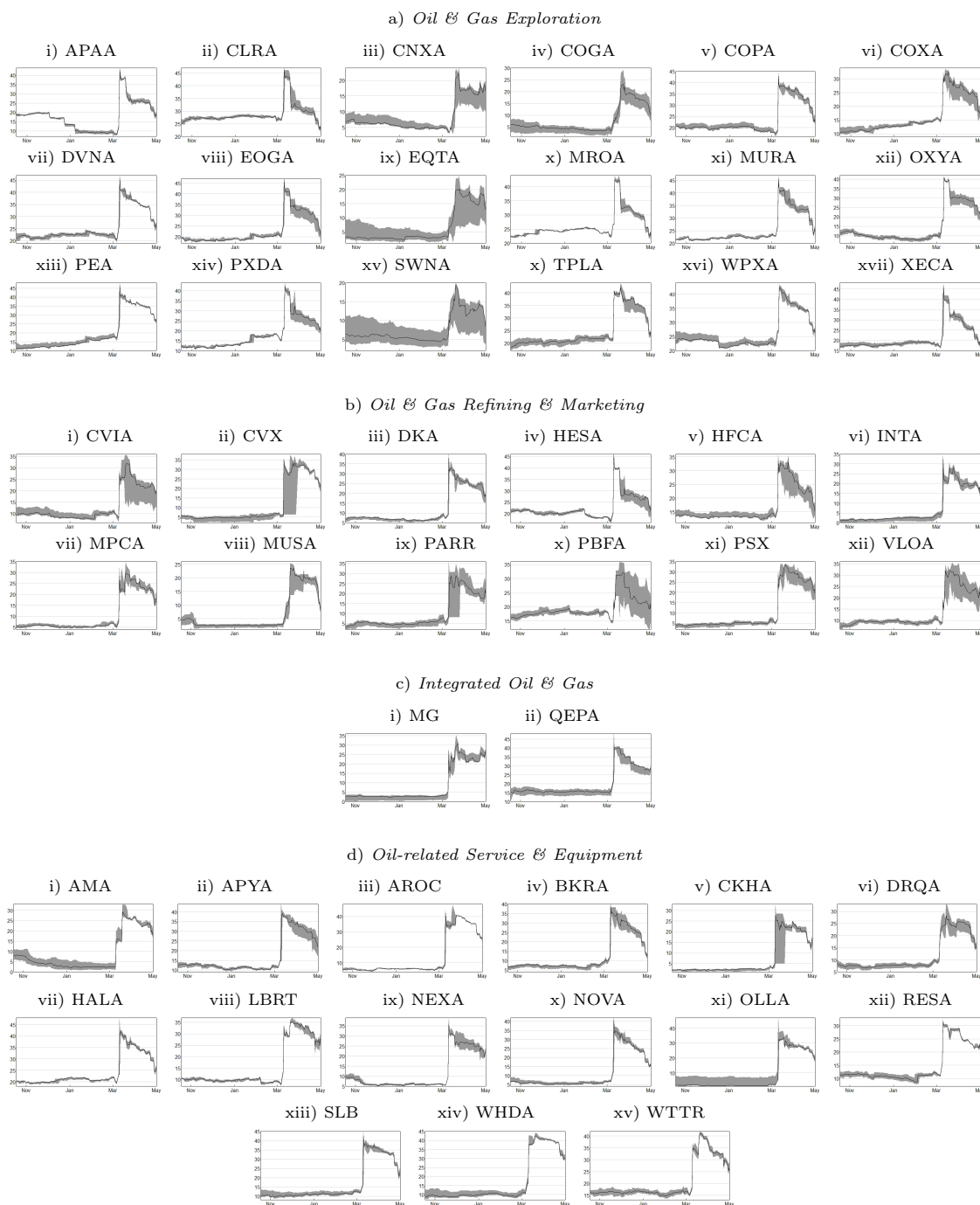
Note: Data was obtained from Thomson Reuters Eikon. All of the test statistics are significant at 95% confidence level

Table A6. DCC-FIGARCH: AIC and SC Results

CLc1	COP	CLc1	EOG	CLc1	OXY	CLc1	PXD	CLc1	CXO	CLc1	COG	CLc1	CLR	CLc1	APA	CLc1	XOM
AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC
-10.1	-9.97	-10.02	-9.9	-9.84	-9.71	-9.83	-9.71	-9.22	-9.1	-9.85	-9.72	-9.26	-9.13	-9.03	-8.9	-11.07	-10.95
CLc1	MRO	CLc1	DVN	CLc1	TPL	CLc1	PE	CLc1	WPX	CLc1	XEC	CLc1	MUR	CLc1	SWN	CLc1	MPC
AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC
-9.77	-9.64	-9.63	-9.5	-9.66	-9.54	-9.28	-9.15	-9.43	-9.31	-9.49	-9.37	-9.41	-9.28	-8.94	-8.82	-9.74	-9.62
CLc1	HFC	CLc1	MUSA	CLc1	CVI	CLc1	DK	CLc1	INT	CLc1	PBF	CLc1	PARR	CLc1	QEP	CLc1	AROC.K
AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC
-10.08	-9.95	-9.37	-9.25	-9.91	-9.78	-9.37	-9.25	-9.81	-9.68	-9.26	-9.13	-10.12	-9.99	-8.35	-8.23	-9.52	-9.39
CLc1	SLB	CLc1	BKR	CLc1	HAL	CLc1	NOV	CLc1	AM	CLc1	WHD	CLc1	DRQ	CLc1	LBRT.K	CLc1	OIH
AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC
-9.82	-9.69	-9.93	-9.8	-9.67	-9.55	-9.32	-9.19	-9.04	-8.92	-9.73	-9.6	-9.43	-9.3	-9.08	-8.96	-8.55	-9.01
CLc1	WMB	CLc1	OKE	CLc1	HESM.K	CLc1	TRGP.K	CLc1	HP	CLc1	ICD	CLc1	ARCH.K	CLc1	BTU	CLc1	NC
AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC	AIC	SC
-10.7	-10.57	-10.67	-10.55	-10.03	-9.9	-9.75	-9.62	-9.69	-9.56	-7.96	-7.84	-9.34	-9.21	-8.36	-8.23	-9.39	-9.26

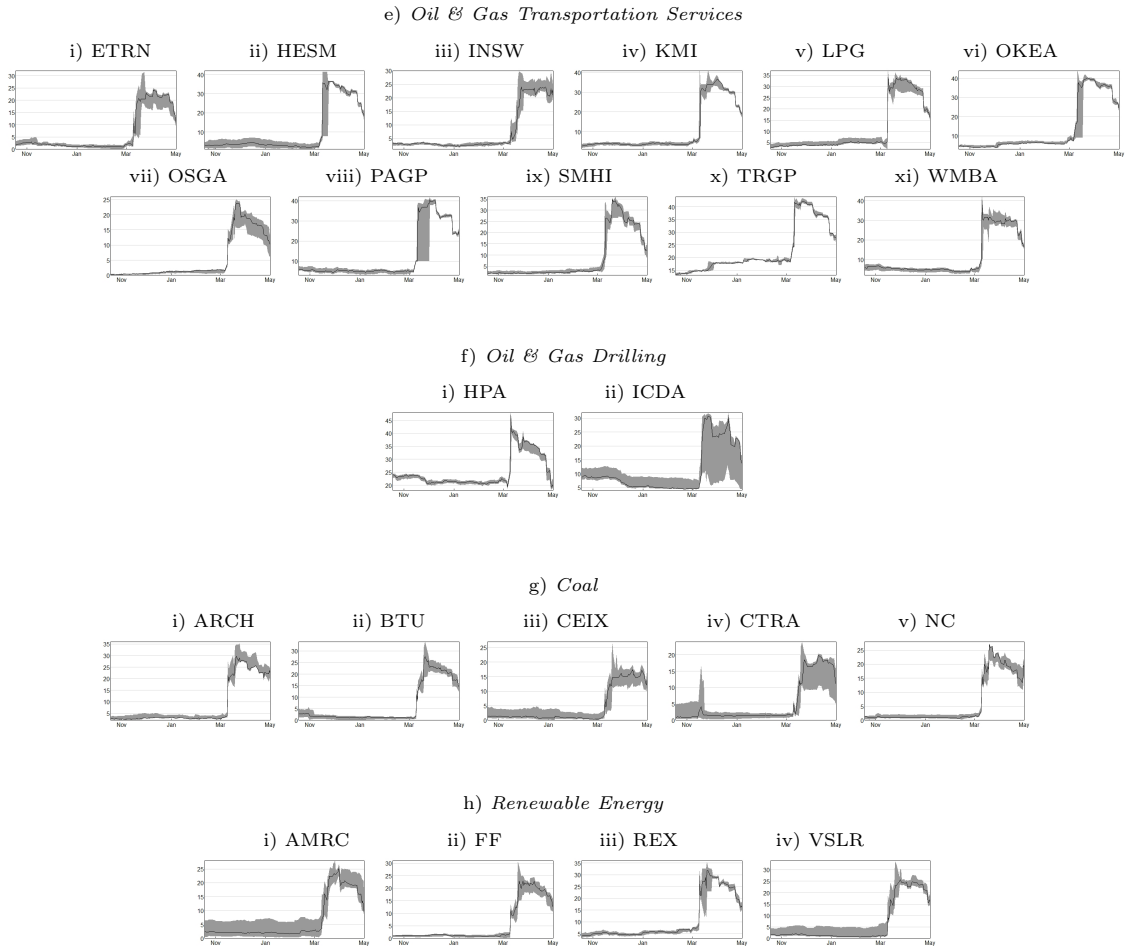
Note: Data was obtained from Thomson Reuters Eikon.

Figure A1. Sensitivity of the index to the VAR lag structure (max, min and median values of the index).



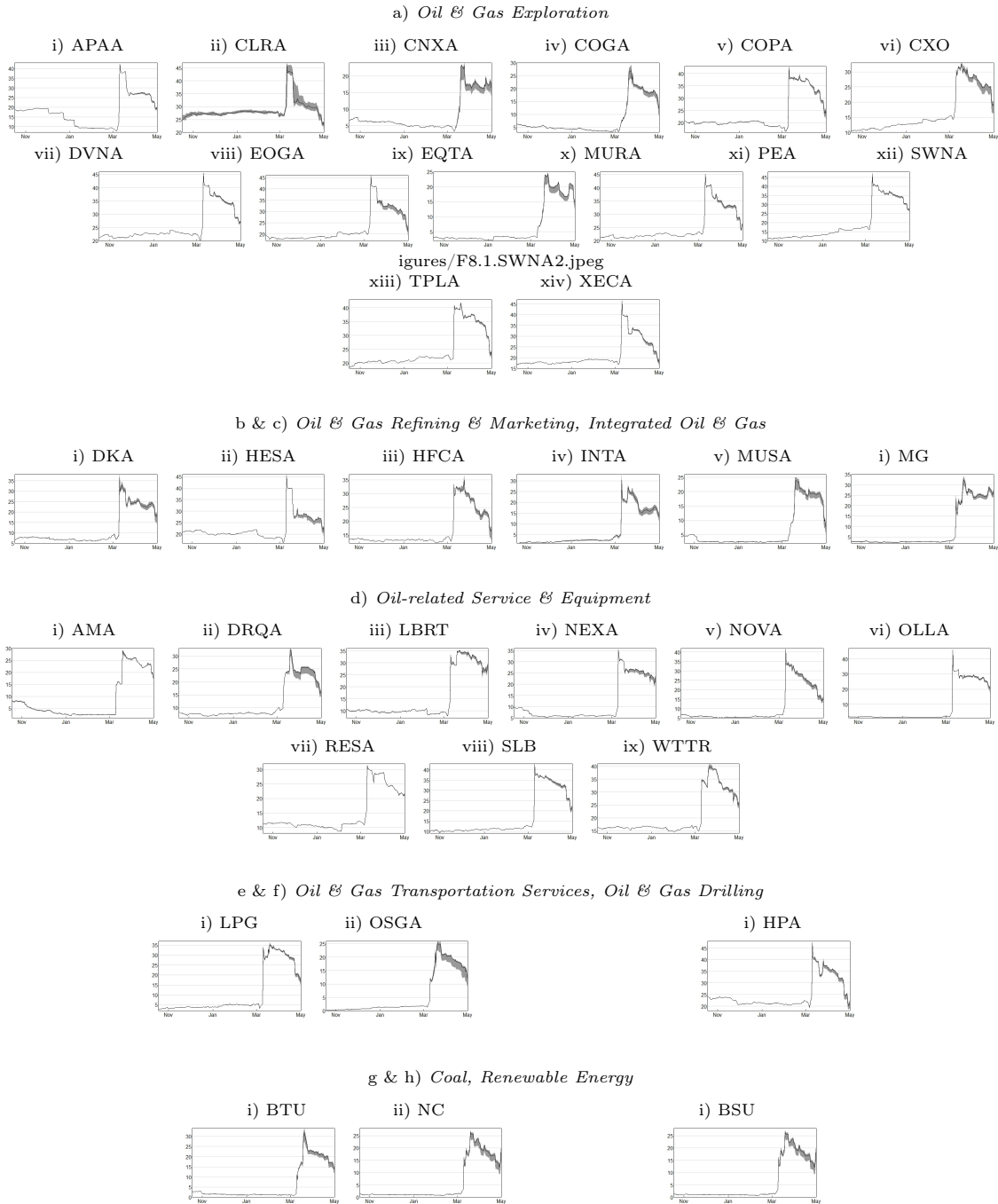
Note: The above figure presents the total spillover plot is not sensitive to the choice of the order of the VAR or the choice of the forecast horizon. For brevity and presentation purposes, only significant results are presented. Further results at varying time-frequencies and variation of methodological structure are available from the authors on request.

Figure A1 (continued). Sensitivity of the index to the VAR lag structure (max, min and median values of the index).



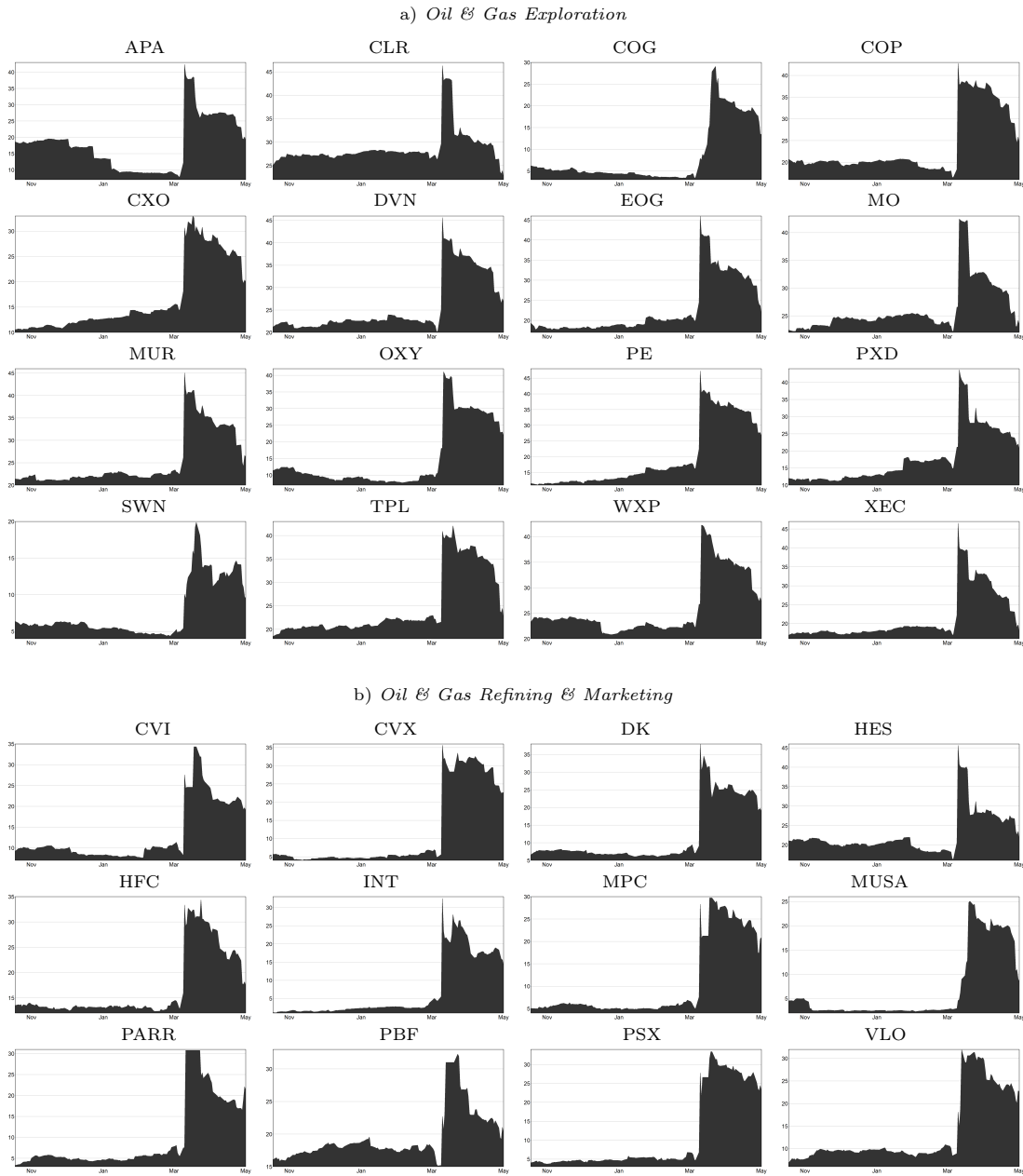
Note: The above figure presents the total spillover plot is not sensitive to the choice of the order of the VAR or the choice of the forecast horizon. For brevity and presentation purposes, only significant results are presented. Further results at varying time-frequencies and variation of methodological structure are available from the authors on request.

Figure A2. Sensitivity of the index to the forecast horizon (min, max and median values over 5- to 10-day horizons)



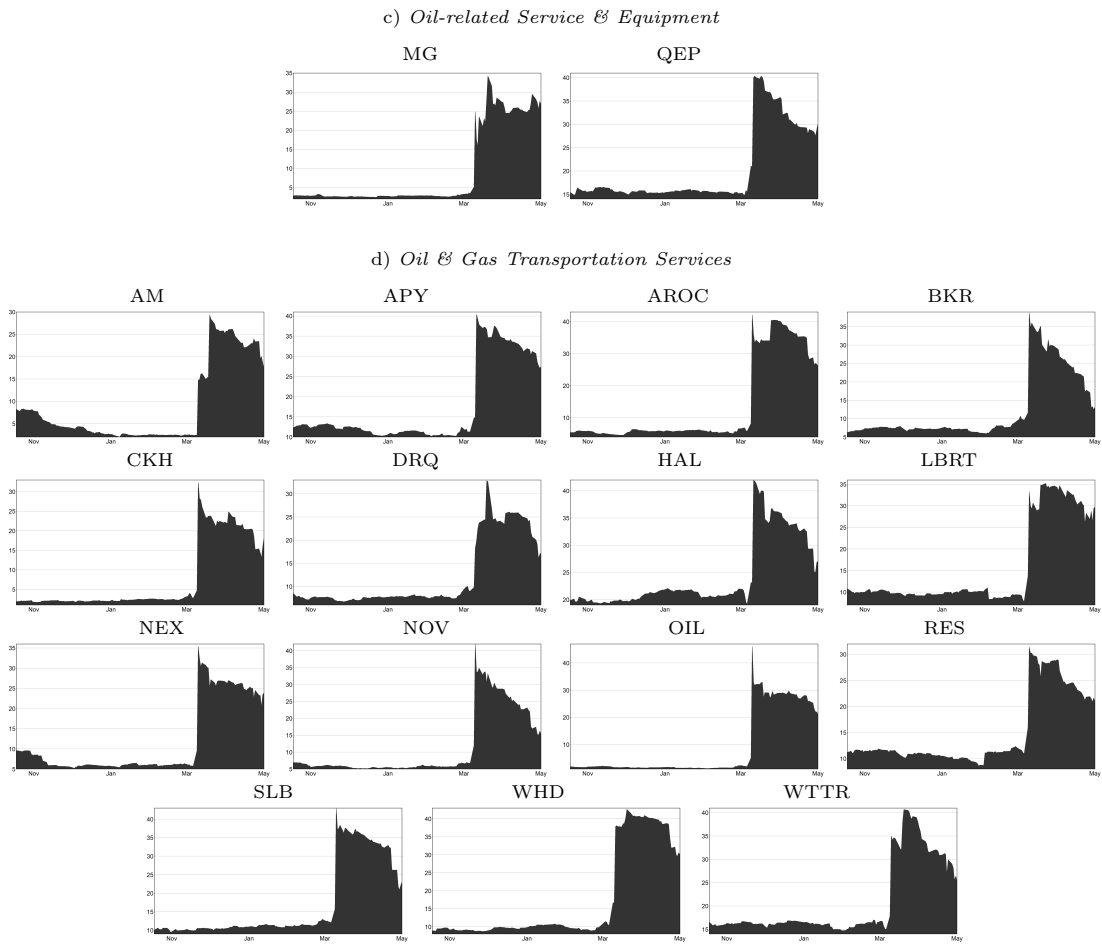
Note: The above figure presents the total spillover plot is not sensitive to the choice of the order of the VAR or the choice of the forecast horizon. For brevity and presentation purposes, only significant results are presented. Further results at varying time-frequencies and variation of methodological structure are available from the authors on request.

Figure B1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, absolute returns, 200-day windows



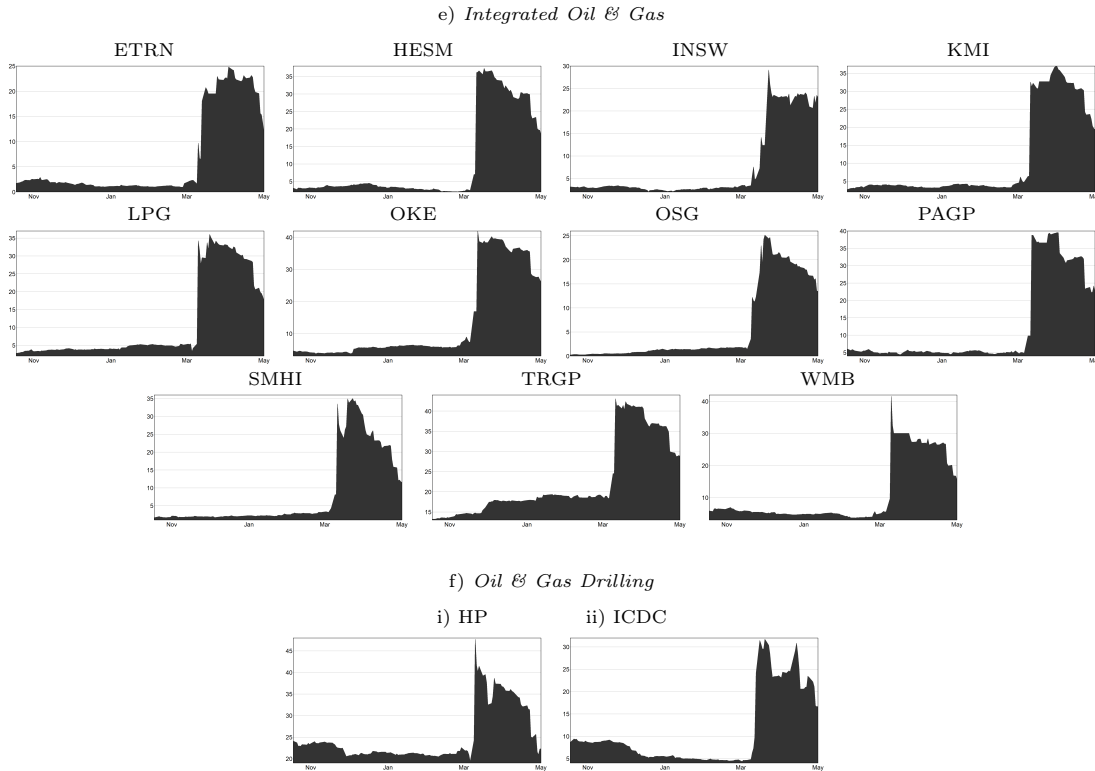
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, absolute returns, 200-day windows



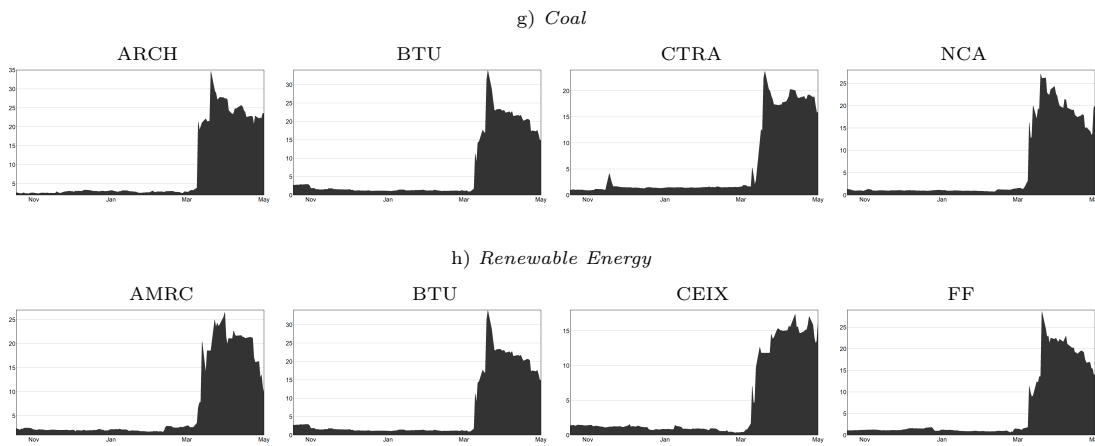
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

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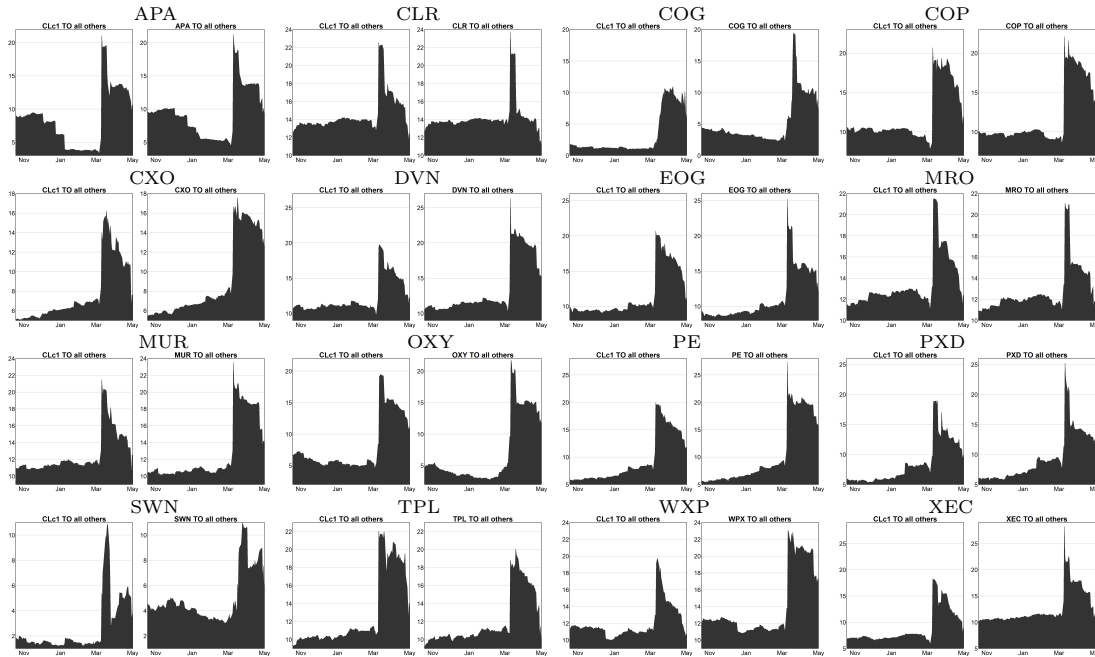
Figure B1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, absolute returns, 200-day windows



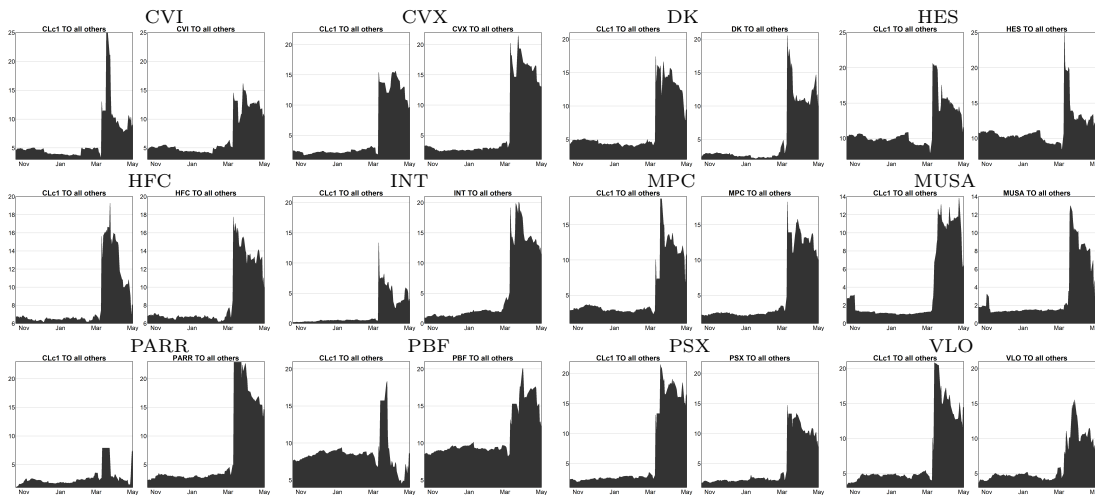
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, absolute returns, 200-day windows

a) Oil & Gas Exploration



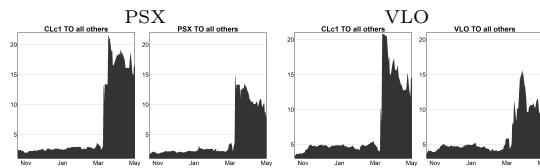
b) Oil & Gas Refining & Marketing



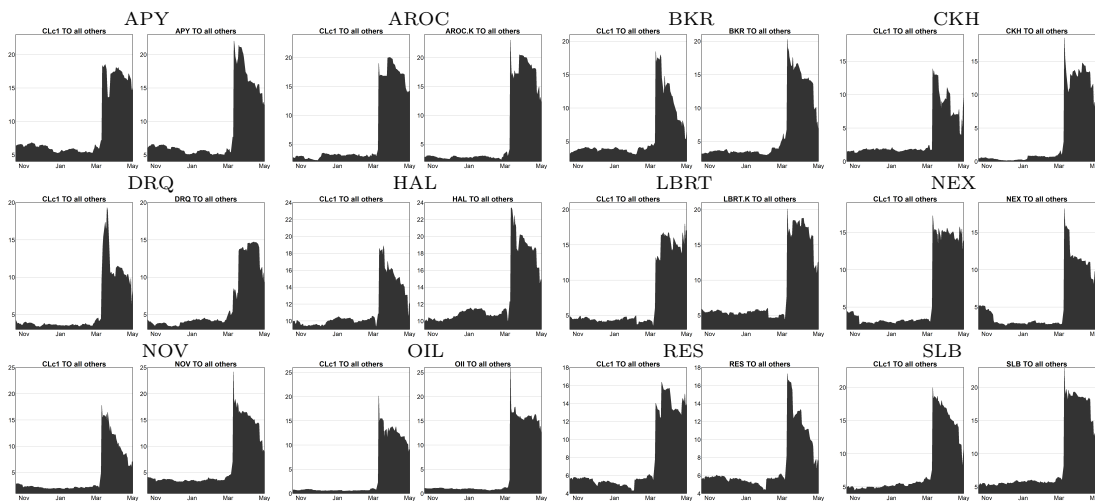
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, absolute returns, 200-day windows (continued)

c) *Oil-related Service & Equipment*



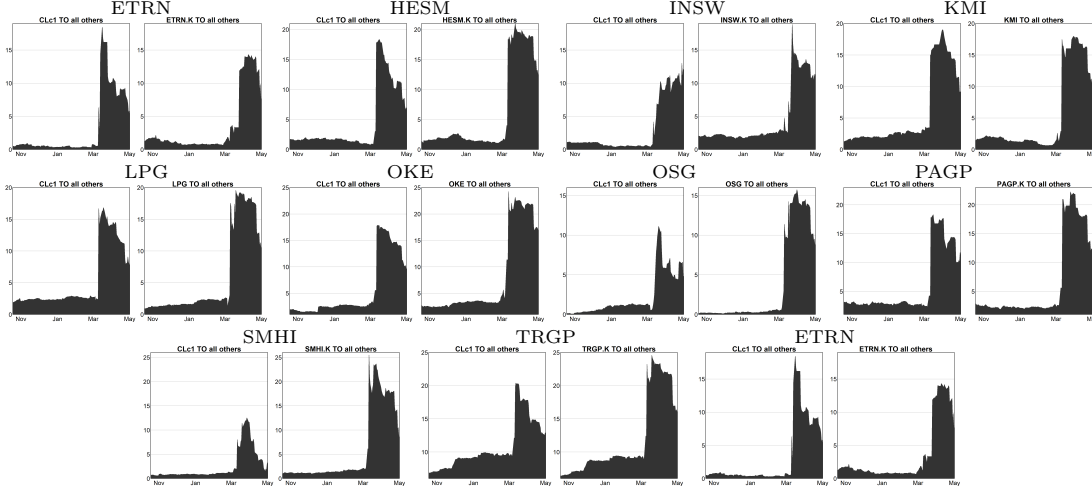
d) *Oil & Gas Transportation Services*



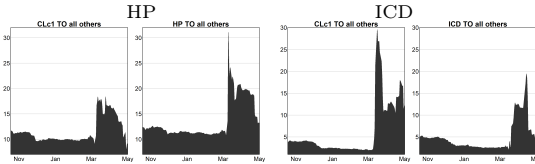
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B2: Total Directional Volatility Spillovers to WTI from each Analysed Sector (continued)

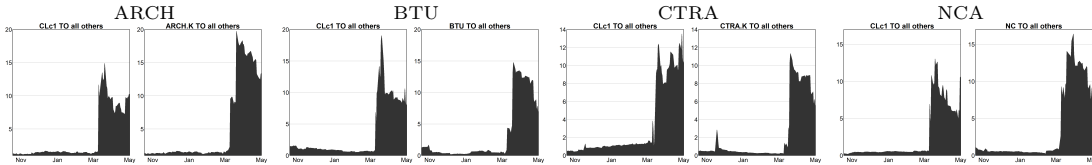
e) *Integrated Oil & Gas*



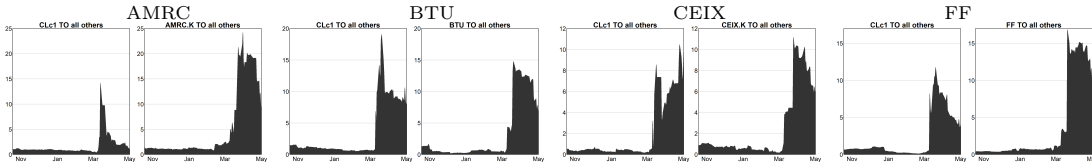
f) *Oil & Gas Drilling*



g) *Coal*



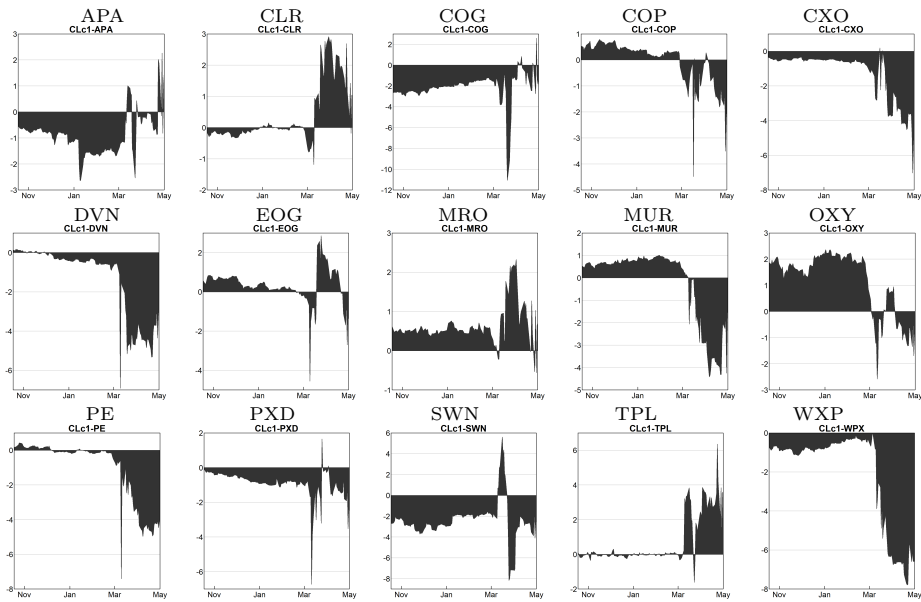
h) *Renewable Energy*



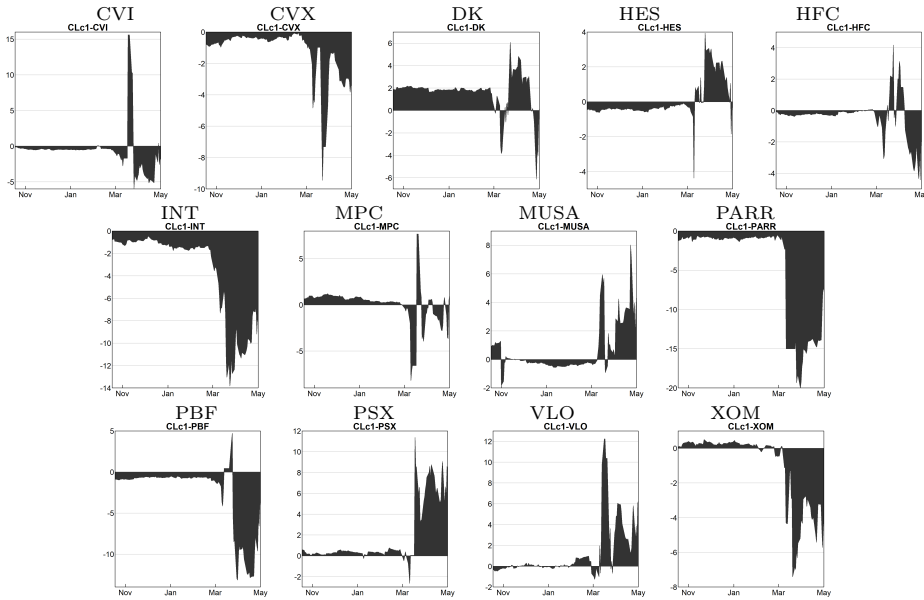
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B3: Net pairwise directional volatility spillovers, absolute returns, 200-day windows

a) Oil & Gas Exploration



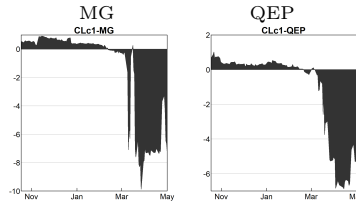
b) Oil & Gas Refining & Marketing



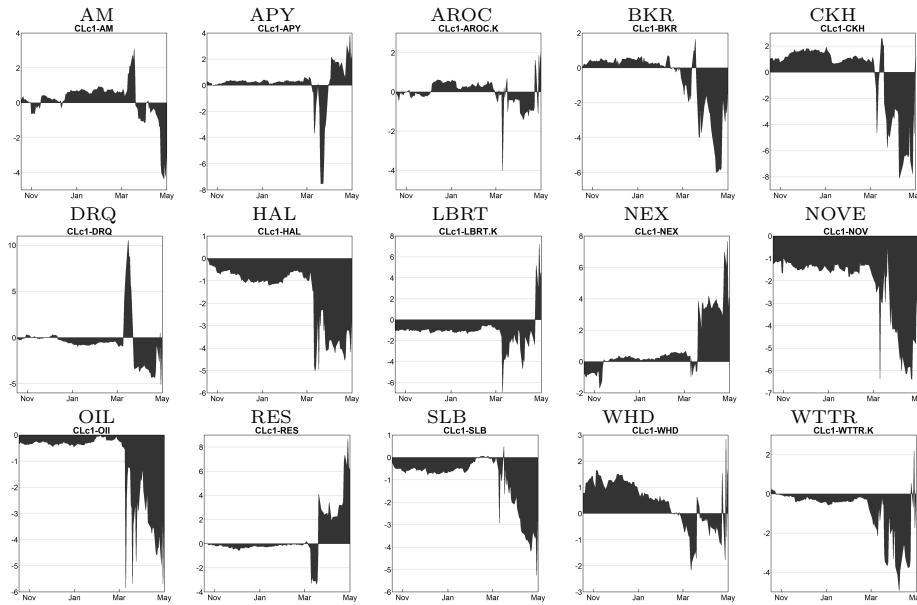
Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B3: Net pairwise directional volatility spillovers, absolute returns, 200-day windows (continued)

c) *Oil-related Service & Equipment*



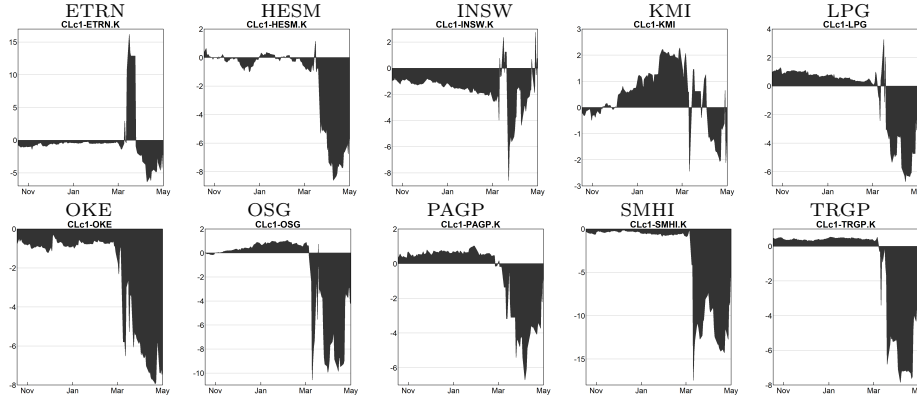
d) *Oil & Gas Transportation Services*



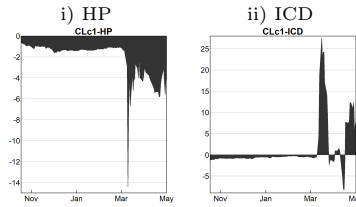
Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B3: Net pairwise directional volatility spillovers, absolute returns, 200-day windows (continued)

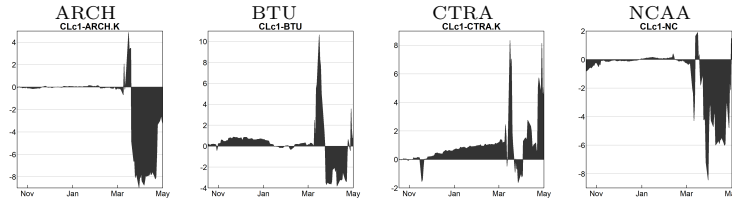
e) *Integrated Oil & Gas*



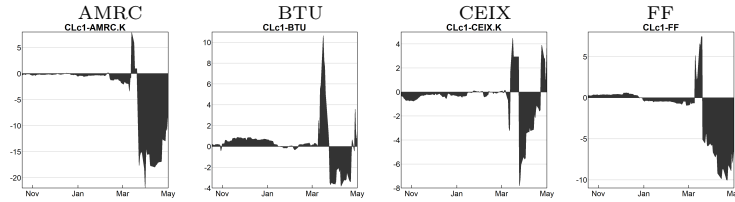
f) *Oil & Gas Drilling*



g) *Coal*



h) *Renewable Energy*



Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Online Appendices (2/3)

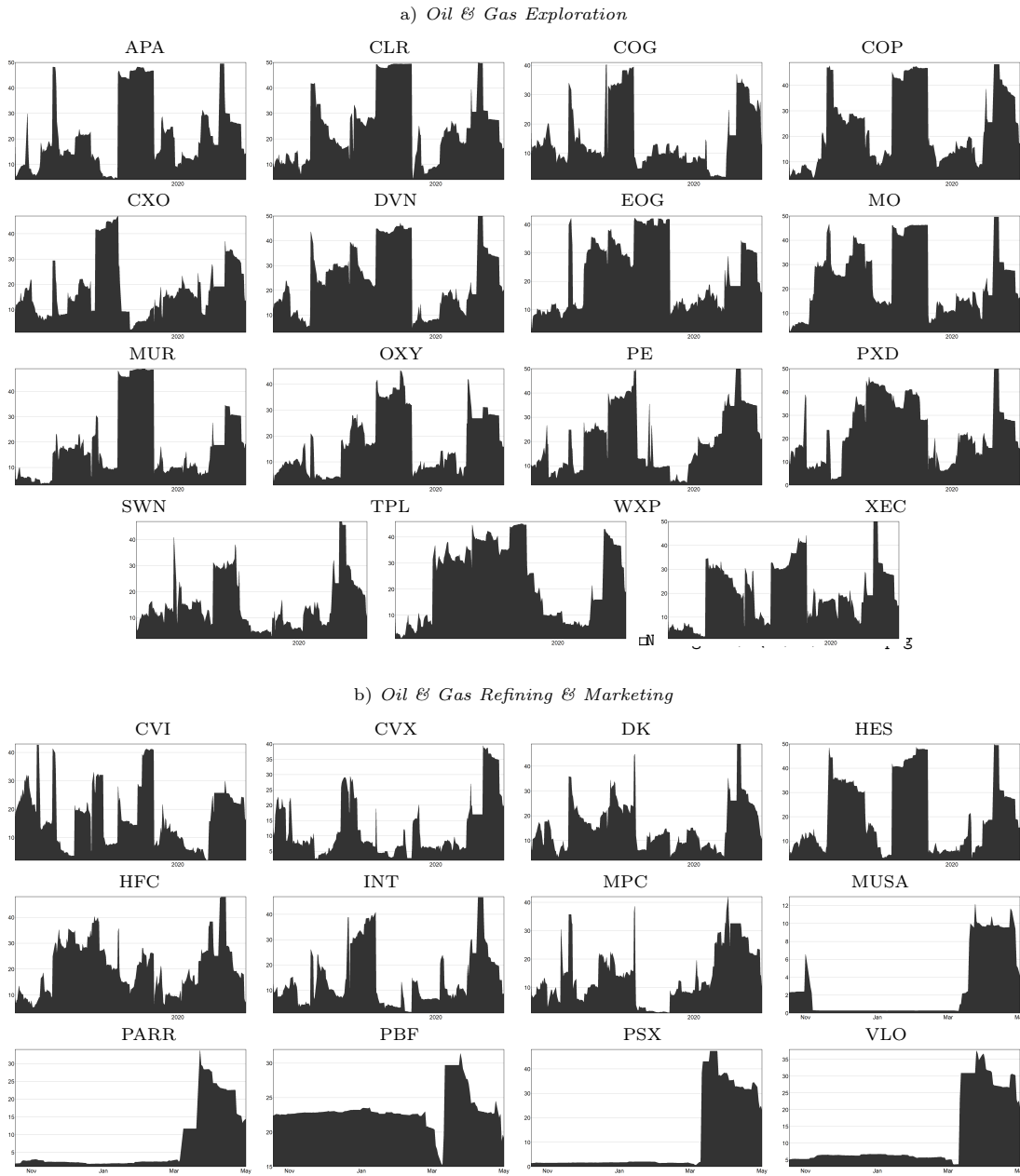
Co-movements and spillovers of oil and renewable firms under extreme conditions: New evidence from negative WTI prices during COVID-19

Abstract

We test for the existence of volatility spillovers and co-movements among energy-focused corporations during the outbreak of the COVID-19 pandemic, inclusive of the April 2020 events where West Texas Intermediate (WTI) oil future prices became negative. Employing the spillover index approach; as well as developing a DCC-FIGARCH conditional correlation framework and using estimated spillover indices built on a generalised vector autoregressive framework in which forecast-error variance decompositions are invariant to the variable ordering, we examine the sectoral transmission mechanisms of volatility shocks and contagion throughout the energy sector. Among several results, we find positive and economically meaningful spillovers from falling oil prices to both renewable energy and coal markets. However, this result is only found for the narrow portion of our sample surrounding the negative WTI event. We interpret our results being directly attributed to a sharp drop in global oil, gas and coal demand, rather than because of a sudden increase in oil supply. While investors observed the US fracking industry losing market share to coal, they also viewed renewables as more reliable mechanism to generate long-term, stable and low-cost supply.

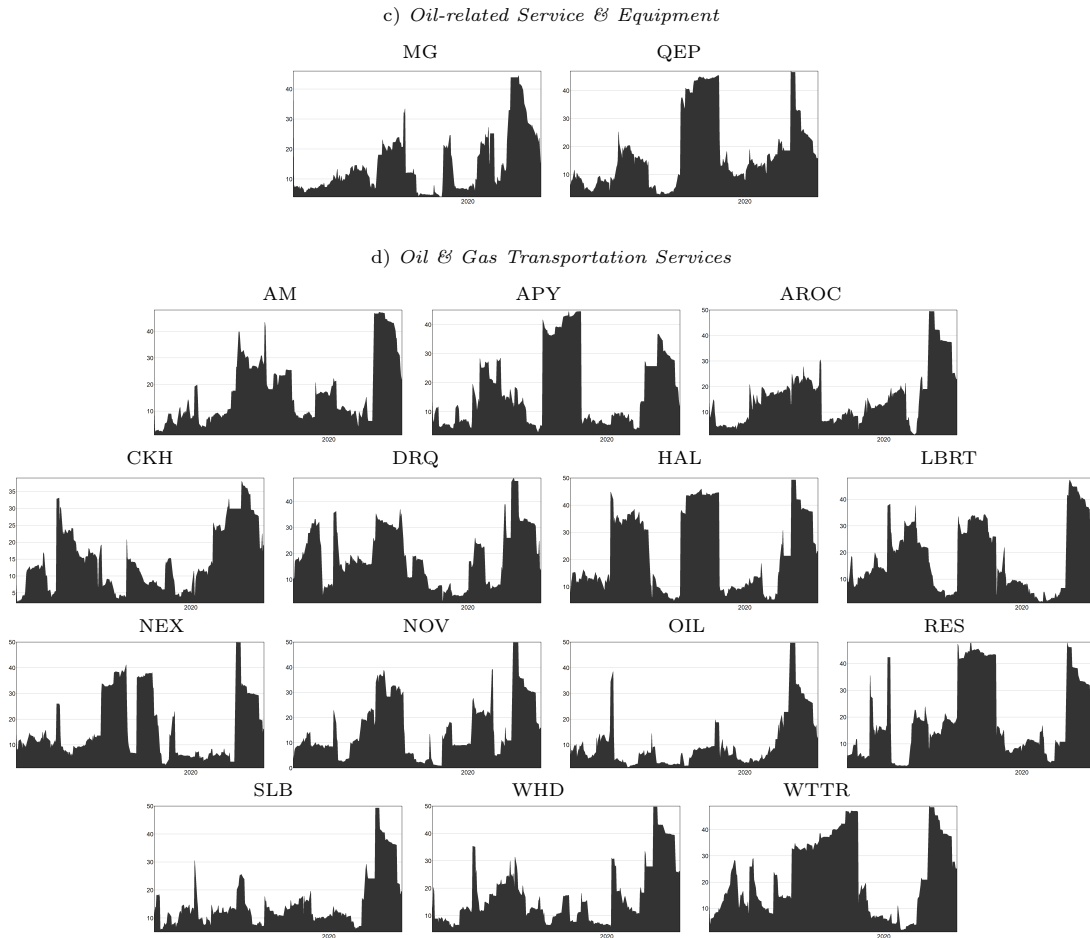
Keywords: Oil prices; Oil and gas corporations; Volatility spillovers; Volatility co-movement; Market linkage; Financial crisis; Contagion.

Figure C1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, squared returns, 50-day methodology



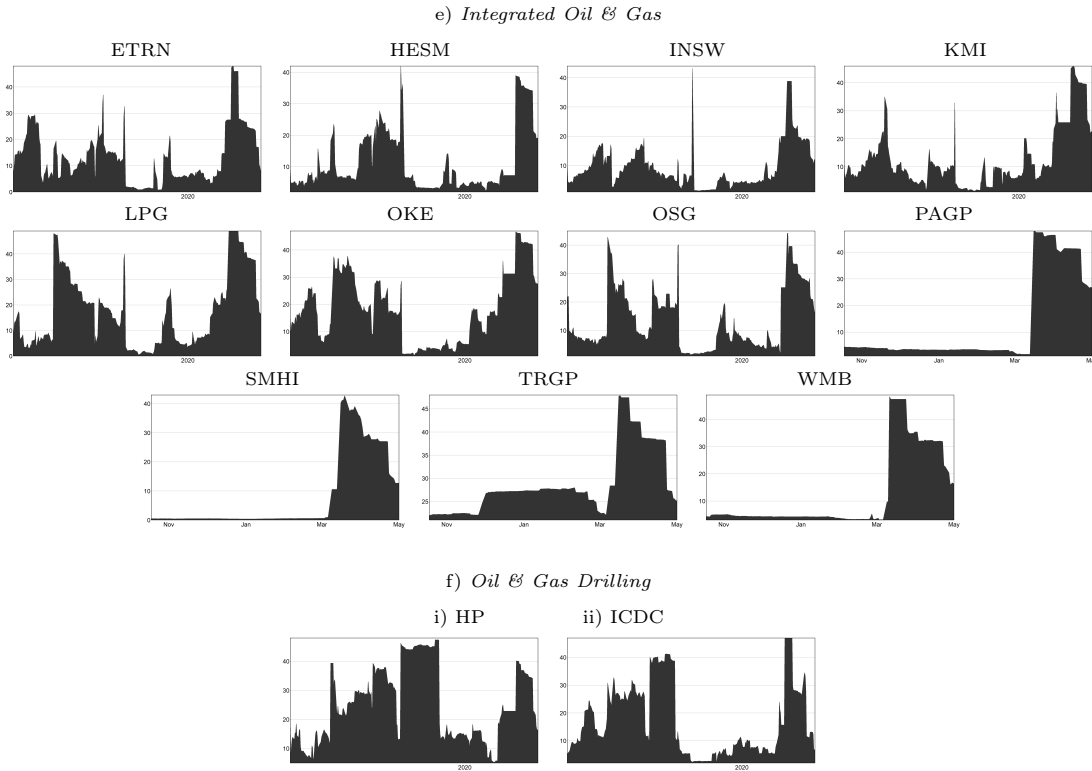
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure C1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, squared returns, 50-day methodology (continued)



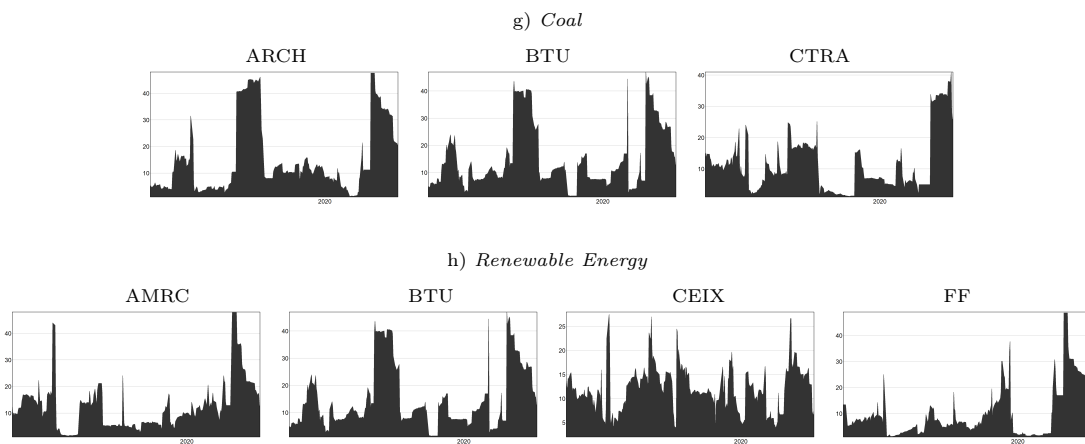
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure C1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, squared returns, 50-day methodology (continued)



Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

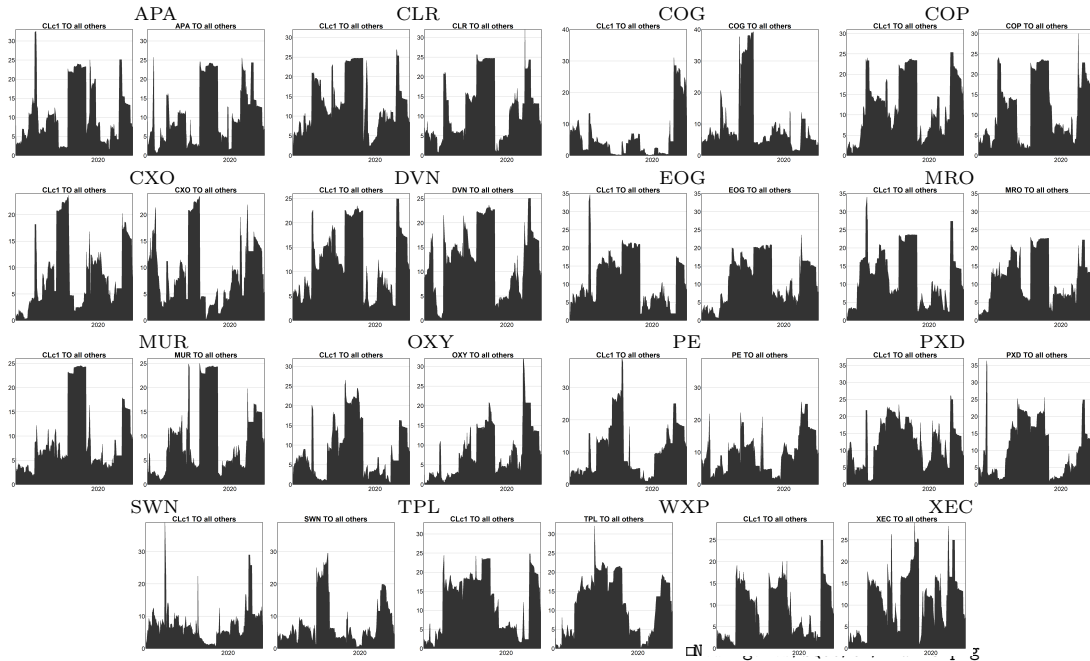
Figure C1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, squared returns, 50-day methodology (continued)



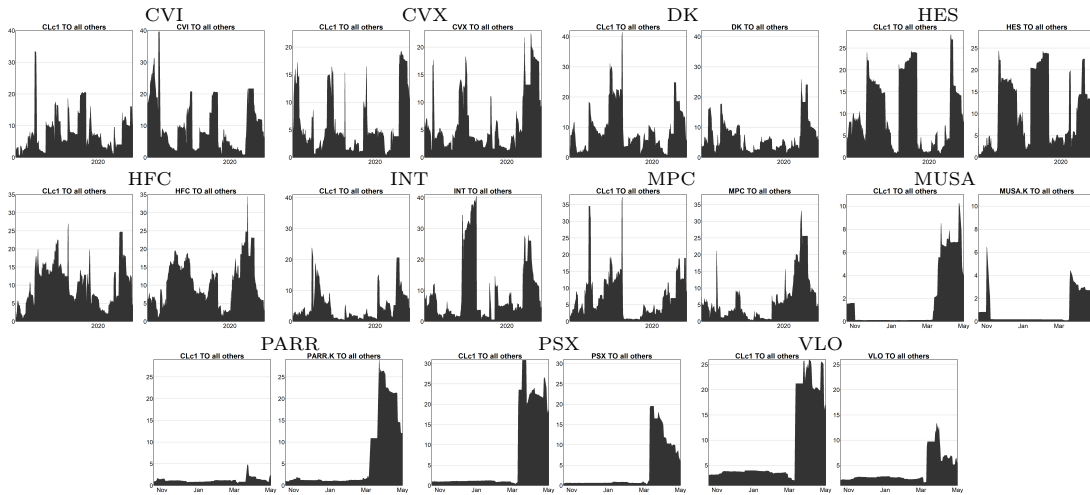
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure C2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, squared returns, 50-day methodology

a) Oil & Gas Exploration



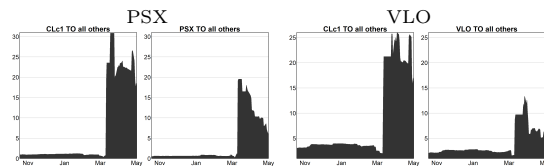
b) Oil & Gas Refining & Marketing



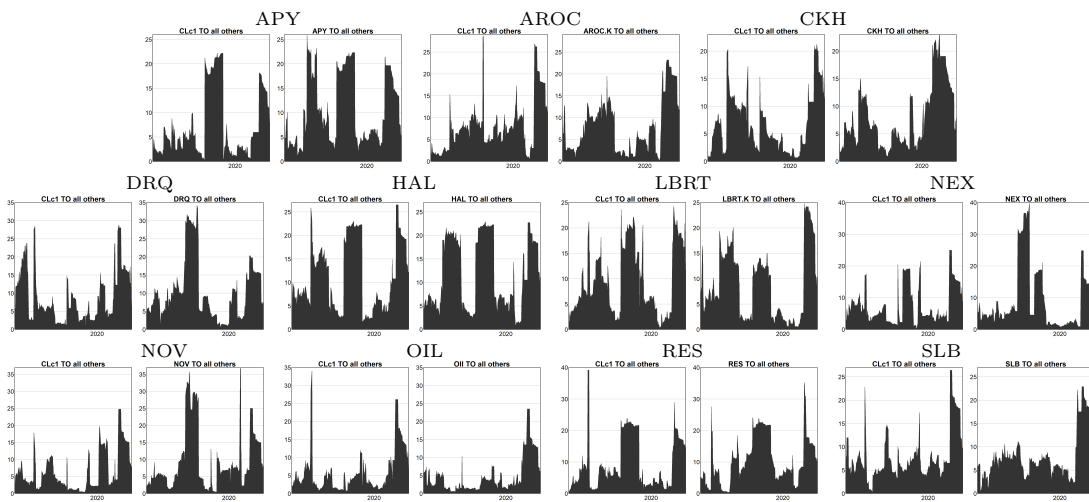
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure C2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, squared returns, 50-day methodology (continued)

c) *Oil-related Service & Equipment*

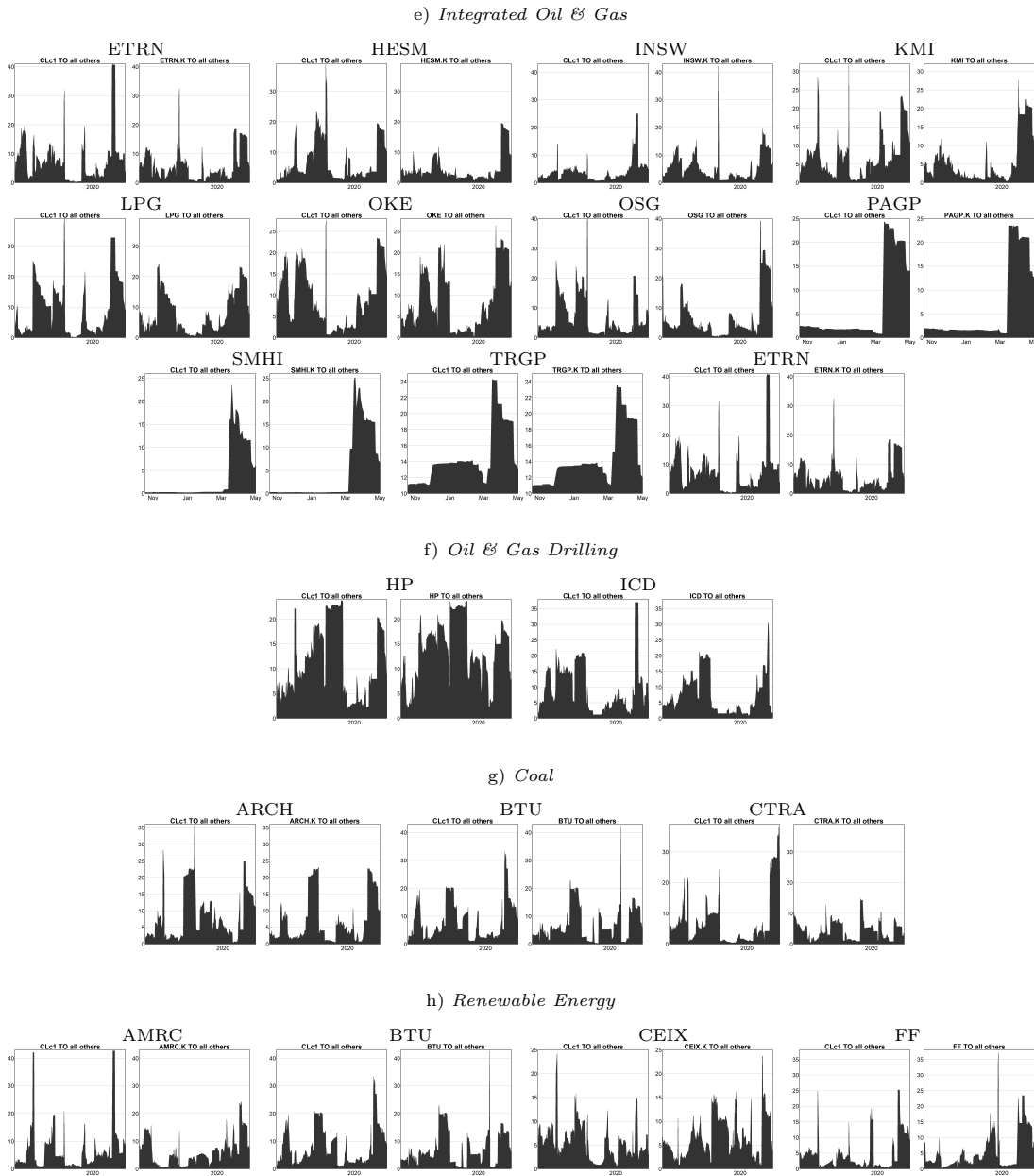


d) *Oil & Gas Transportation Services*



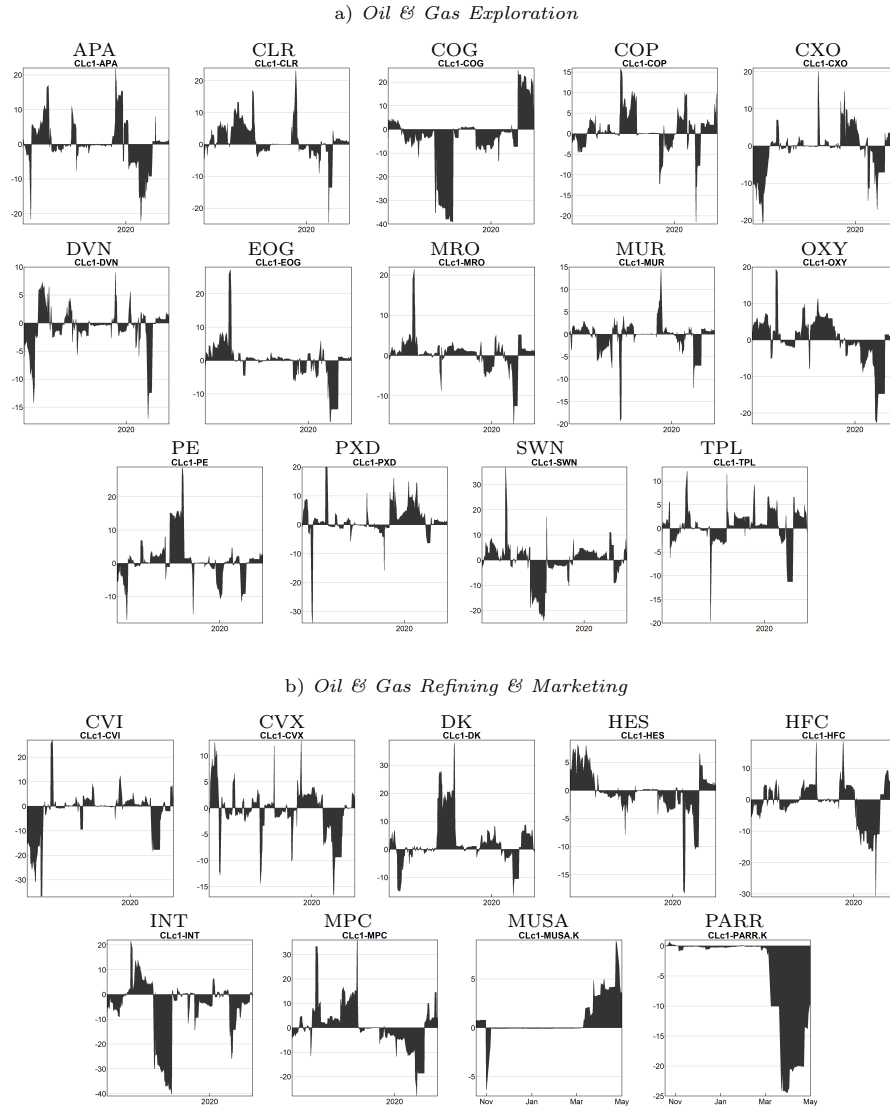
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure C2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, squared returns, 50-day methodology (continued)



Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

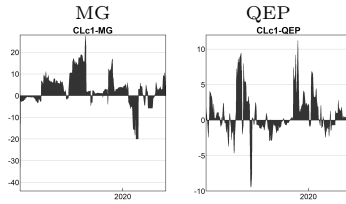
Figure C3: Net pairwise directional volatility spillovers, squared returns, 50-day methodology



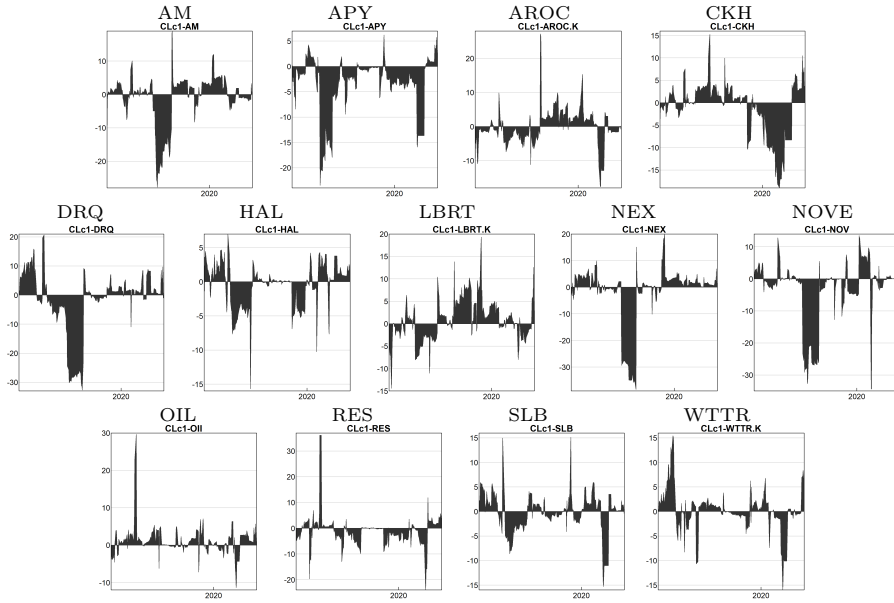
Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure C3: Net pairwise directional volatility spillovers, squared returns, 50-day methodology (continued)

c) *Oil-related Service & Equipment*



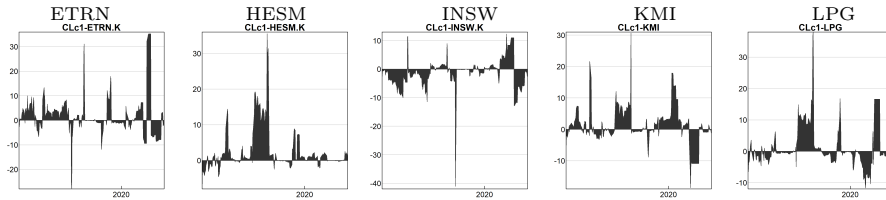
d) *Oil & Gas Transportation Services*



Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

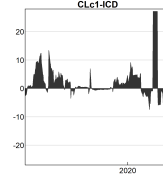
Figure C3: Net pairwise directional volatility spillovers, squared returns, 50-day methodology (continued)

e) *Integrated Oil & Gas*

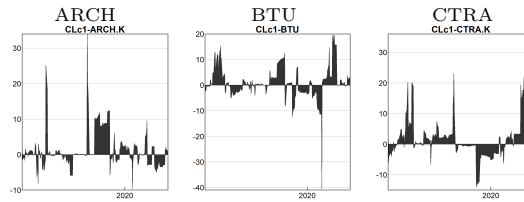


f) *Oil & Gas Drilling*

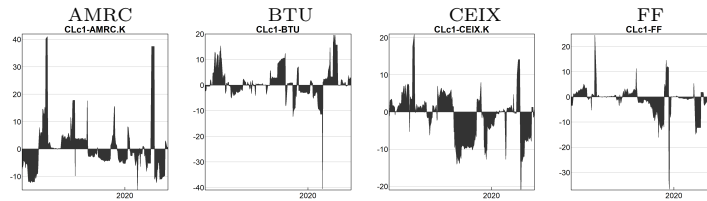
i) ICD



g) *Coal*



h) *Renewable Energy*



Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Online Appendices (3/3)

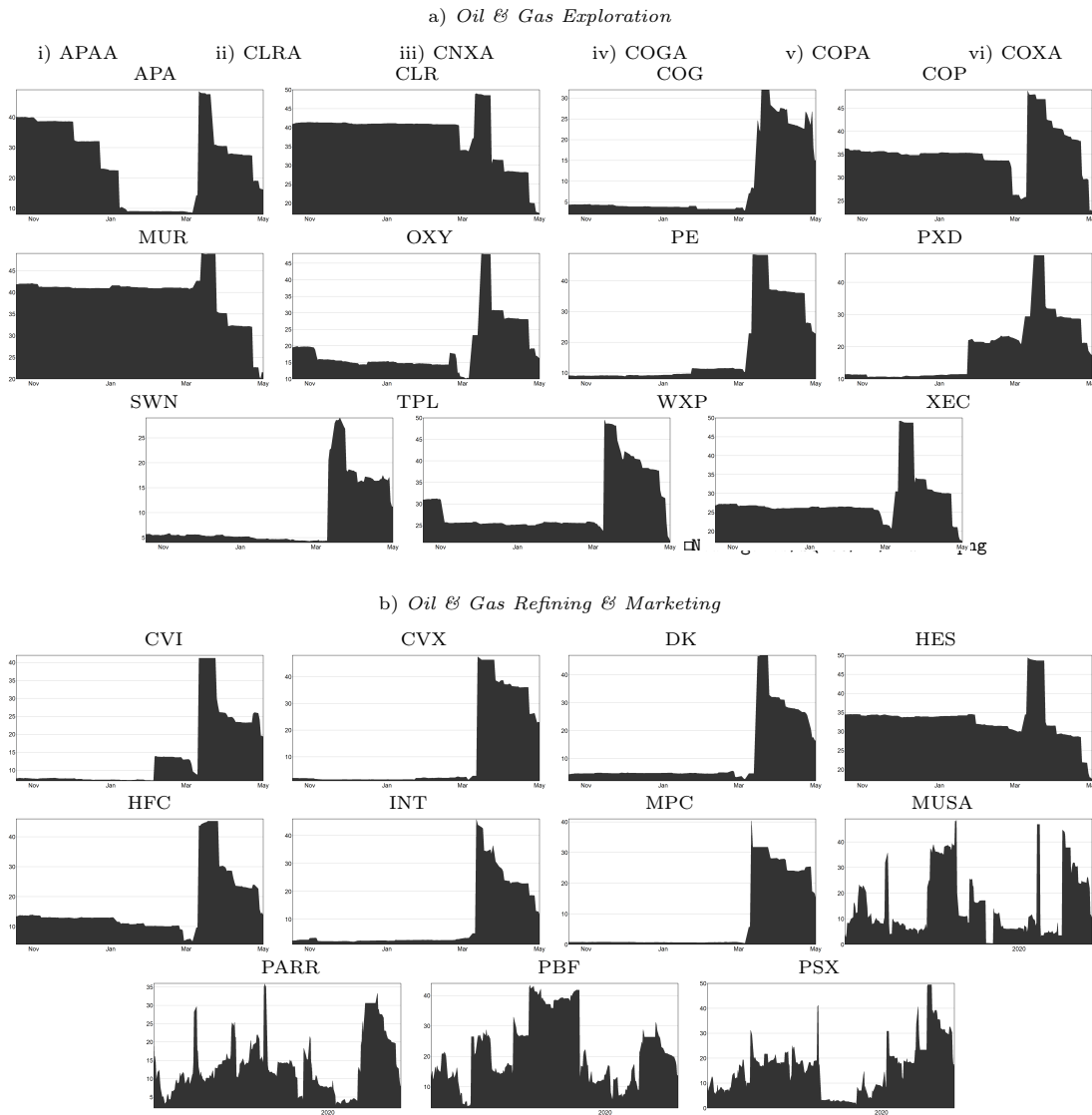
Co-movements and spillovers of oil and renewable firms under extreme conditions: New evidence from negative WTI prices during COVID-19

Abstract

We test for the existence of volatility spillovers and co-movements among energy-focused corporations during the outbreak of the COVID-19 pandemic, inclusive of the April 2020 events where West Texas Intermediate (WTI) oil future prices became negative. Employing a spillover index approach as well as developing a DCC-FIGARCH conditional correlation framework and using estimated spillover indices built on a generalised vector autoregressive framework in which forecast-error variance decompositions are invariant to the variable ordering, we examine the sectoral transmission mechanisms of volatility shocks and contagion throughout the energy sector. Among several results, we find positive and economically meaningful spillovers from falling oil prices to both renewable energy and coal markets. However, this result is only found for the narrow portion of our sample surrounding the negative WTI event. We interpret our results being directly attributed to a sharp drop in global oil, gas and coal demand, rather than because of a sudden increase in oil supply. While investors observed the US fracking industry losing market share to coal, they also viewed renewables as more reliable mechanism to generate long-term, stable and low-cost supply.

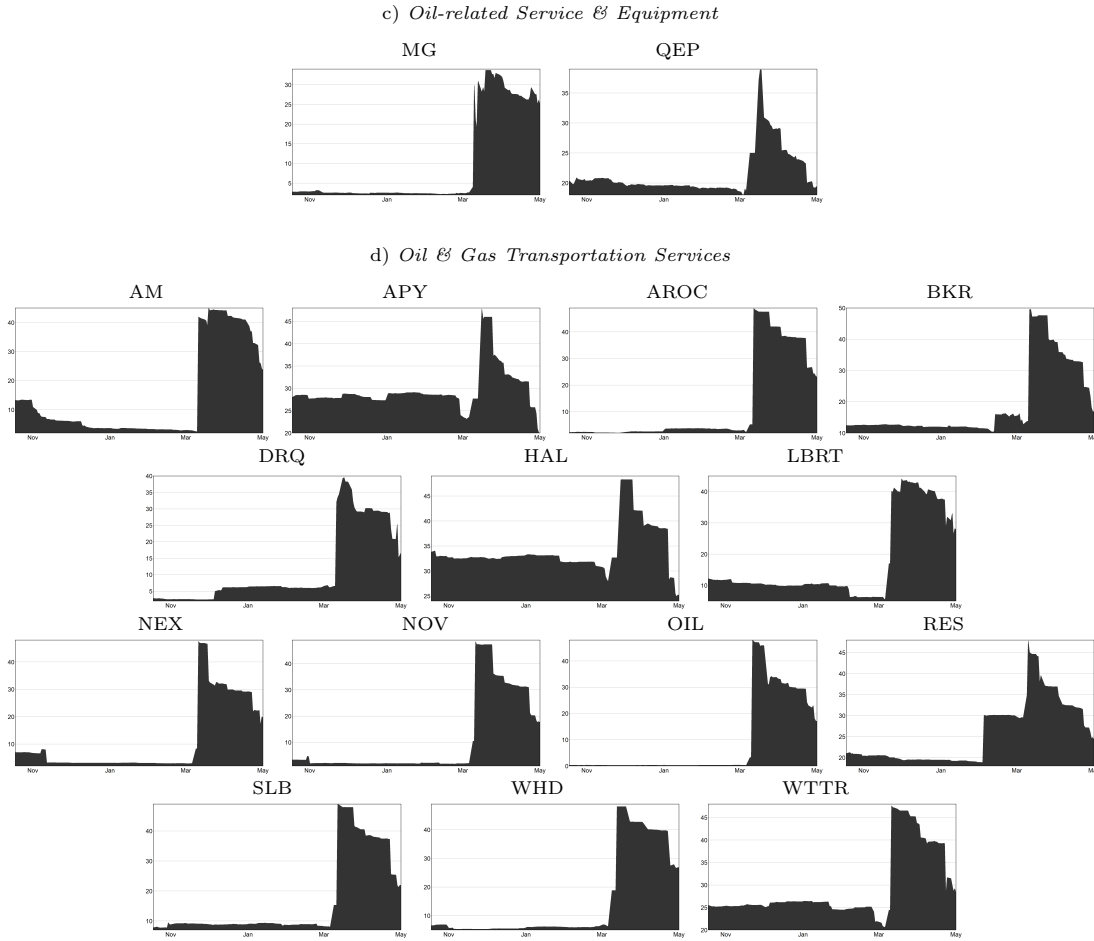
Keywords: Oil prices; Oil and gas corporations; Volatility spillovers; Volatility co-movement; Market linkage; Financial crisis; Contagion.

Figure D1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, squared returns, 200-day methodology



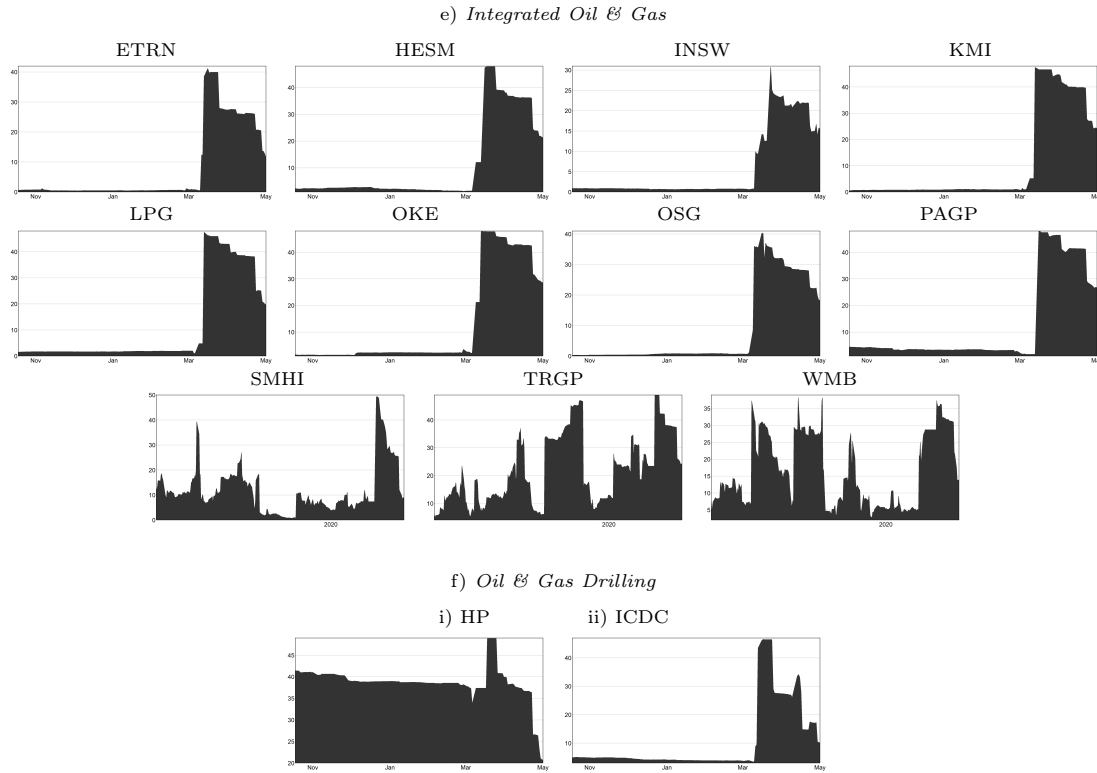
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, absolute returns, 200-day windows



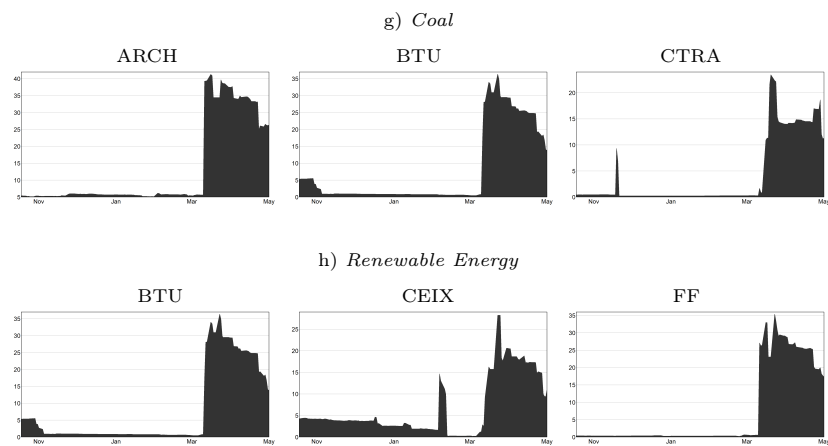
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure B1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, absolute returns, 200-day windows



Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

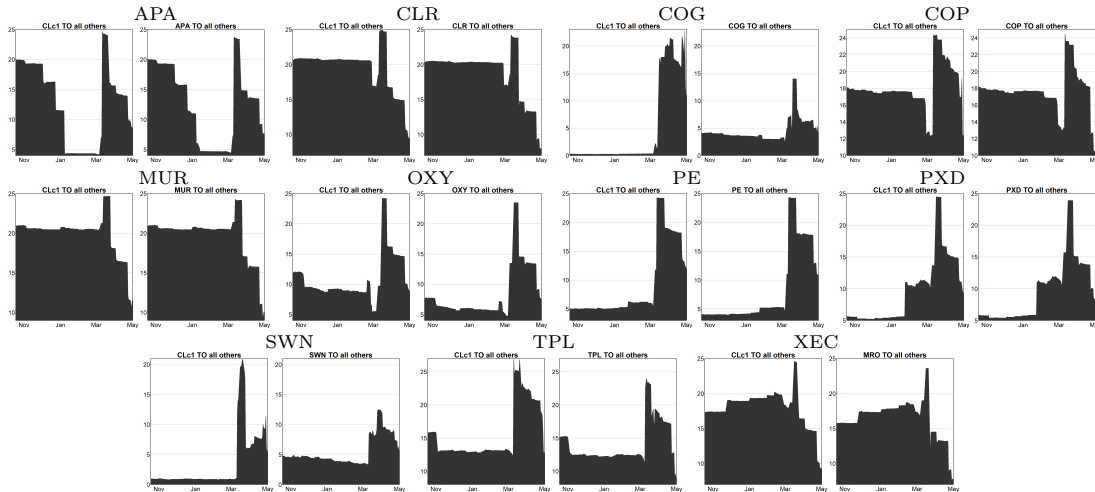
Figure B1: Total Directional Volatility Spillovers from WTI onto each Analysed Sector, absolute returns, 200-day windows



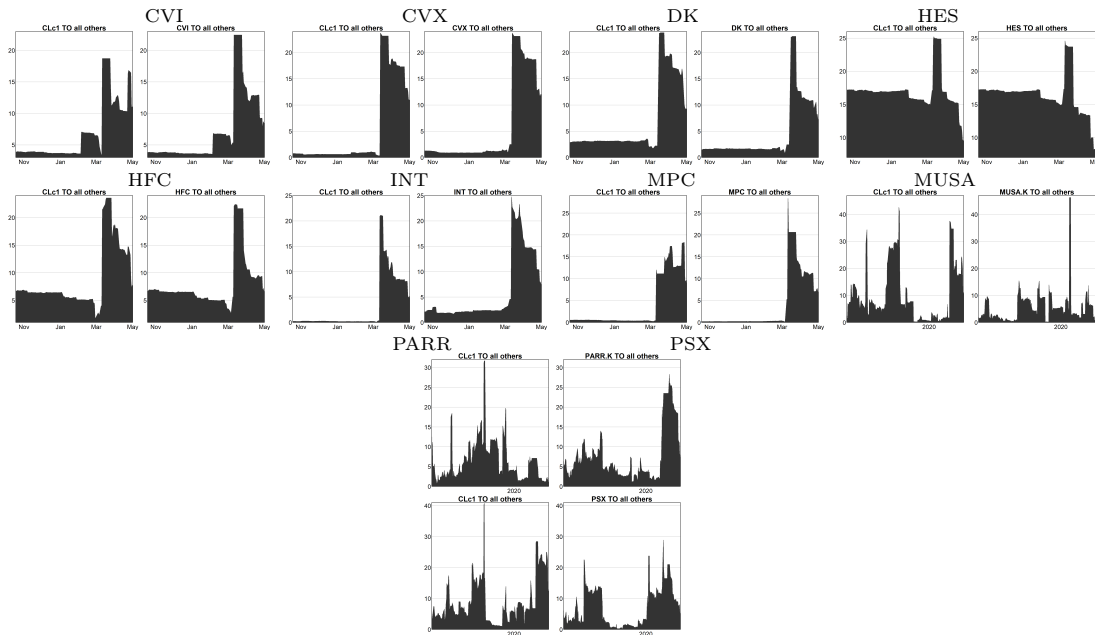
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Figure D2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, squared returns, 200-day methodology

a) Oil & Gas Exploration



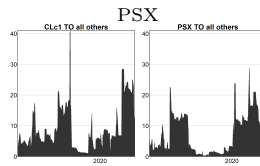
b) Oil & Gas Refining & Marketing



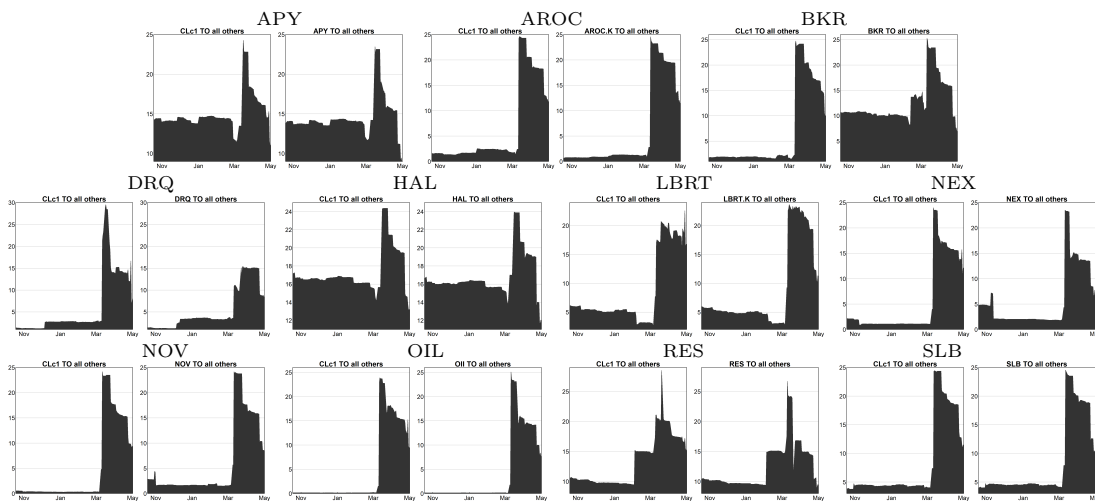
Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure D2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, squared returns, 200-day methodology (continued)

c) Oil-related Service & Equipment

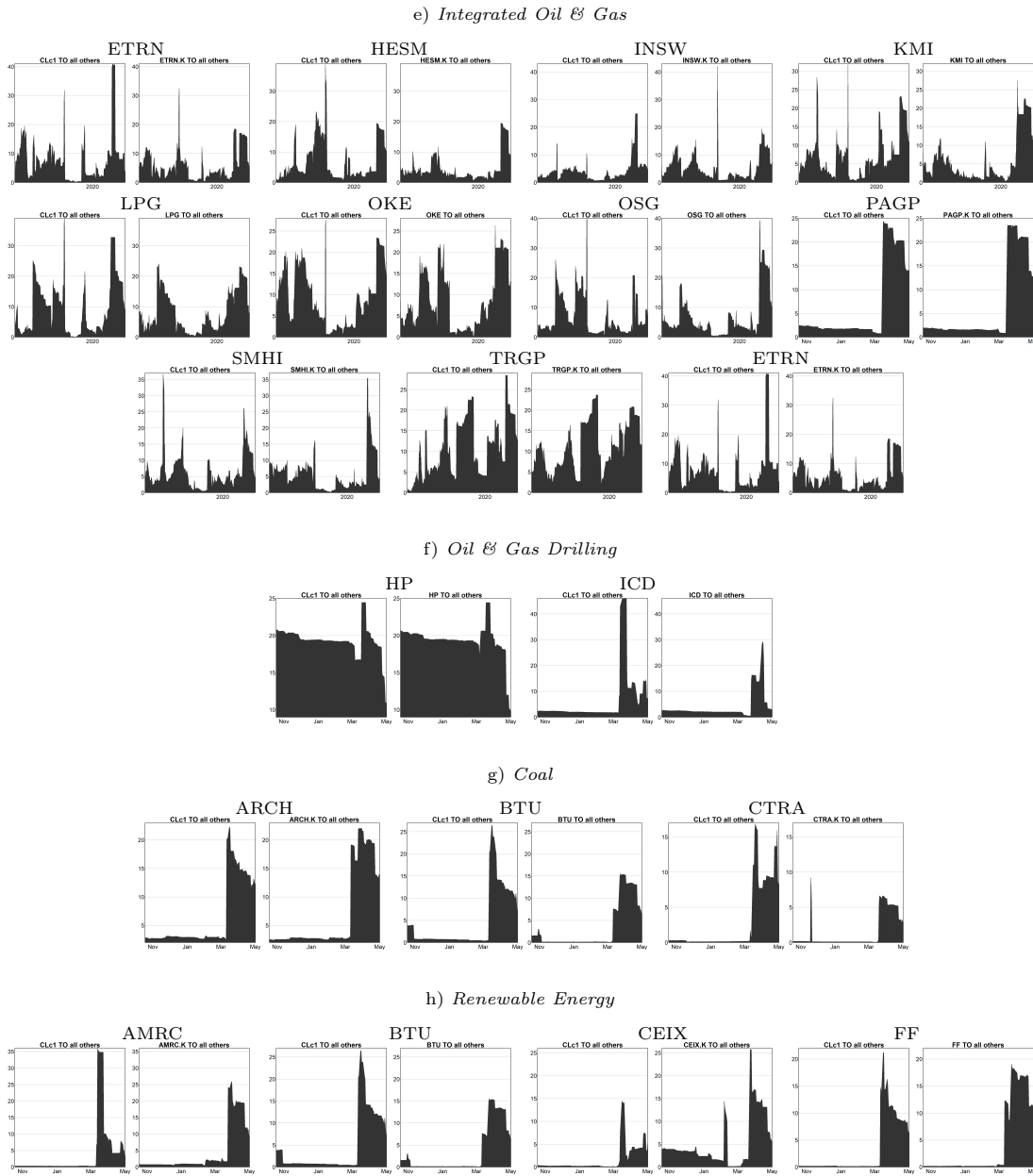


d) Oil & Gas Transportation Services



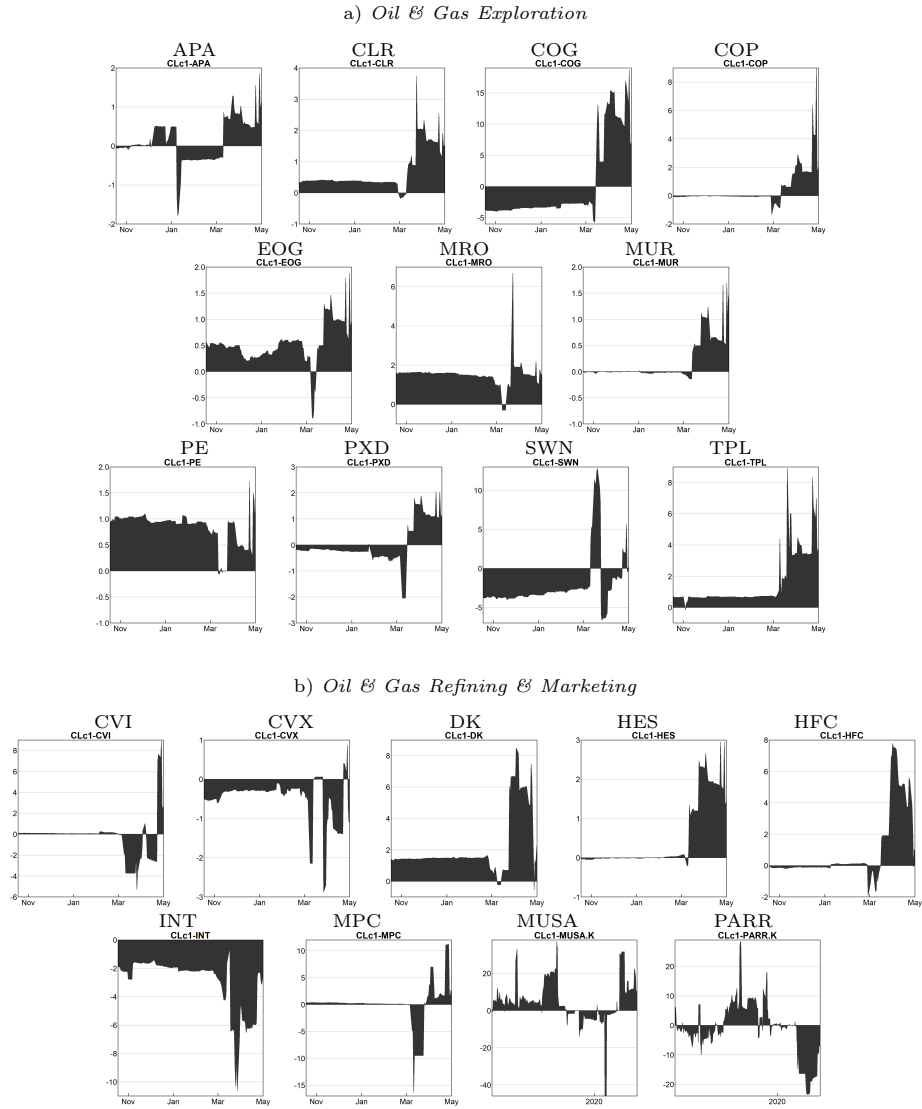
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Figure D2: Total Directional Volatility Spillovers to WTI from each Analysed Sector, squared returns, 200-day methodology (continued)



Note: The above Figure represents the total directional volatility spillovers from WTI upon each stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

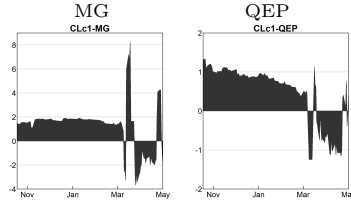
Figure D3: Net pairwise directional volatility spillovers, squared returns, 200-day methodology



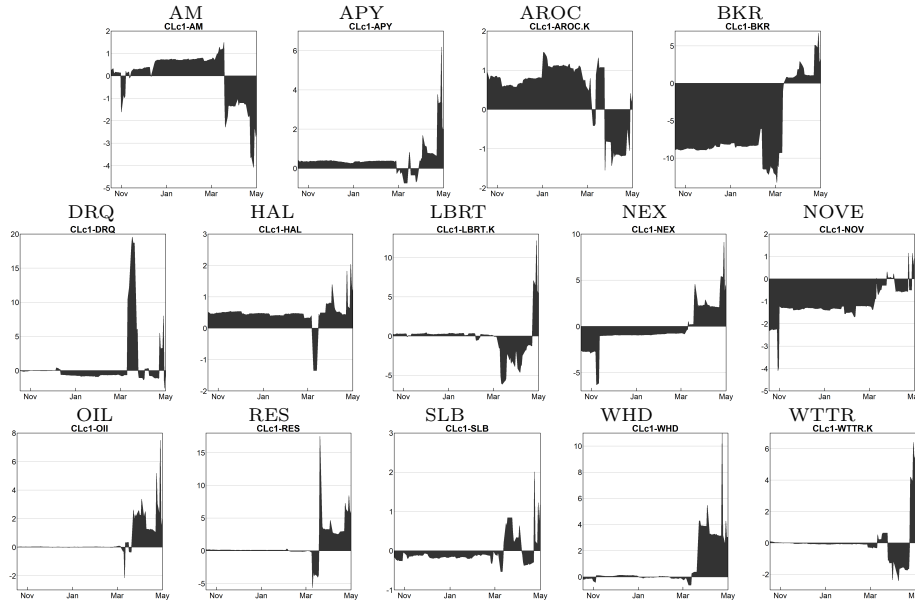
Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.

Figure D3: Net pairwise directional volatility spillovers, squared returns, 200-day methodology (continued)

c) *Oil-related Service & Equipment*



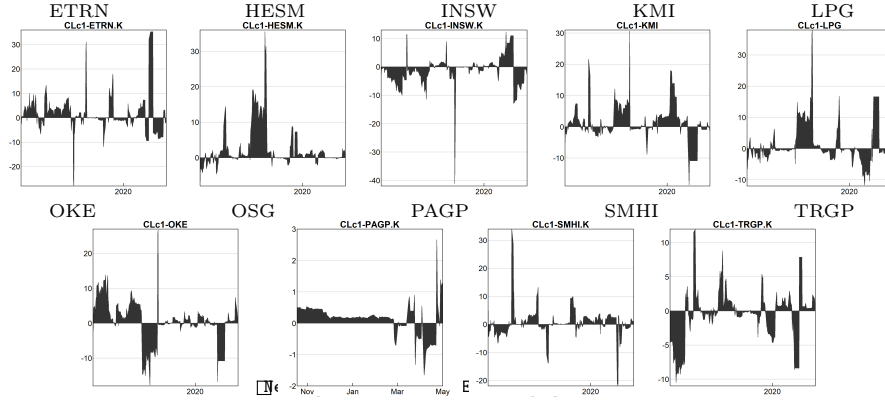
d) *Oil & Gas Transportation Services*



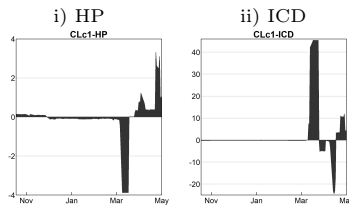
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Figure D3: Net pairwise directional volatility spillovers, squared returns, 200-day methodology (continued)

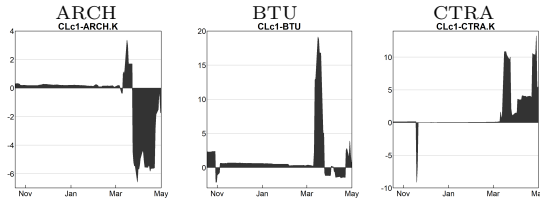
e) *Integrated Oil & Gas*



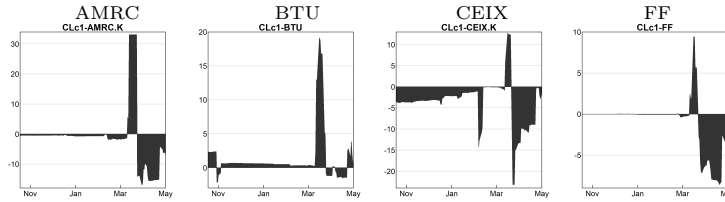
f) *Oil & Gas Drilling*



g) *Coal*



h) *Renewable Energy*



Note: The above Figure represents the net pairwise directional volatility spillovers by stated energy sector. To examine spillovers in the volatility of WTI during the outbreak of the COVID-19 pandemic and the subsequent effects of negative oil prices, and the effects of each event on energy-companies in the US, we apply the generalised version of the spillover index.