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Equity, Commodity, and Distillate Risks During Industrial Transformation: Innovation in the Oil & Gas Industry Using GARCH Difference-in-Decompositions

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# Equity, Commodity, and Distillate Risks During Industrial Transformation: Innovation in the Oil & Gas Industry Using GARCH Difference-in-Decompositions

## Abstract

The oil and gas industry's early 2000's fracking and horizontal drilling revolution realigned the industry and larger economies. This study uses New Growth Theory to evaluate innovation across an industry with various integrated but distinct upstream, midstream, and downstream units. Two issues are considered. First, how did Independent returns vary within the industry by equity, commodity, and distillate risks relative to Integrated majors before and after the fracking revolution? The fracking revolution changed within-group technology that favored Independent firms who outperformed larger Integrated producers. Second, how did upstream, midstream, and downstream risks vary across the industry by equity, commodity, and distillates relative to Integrated firms before and after the fracking revolution? Exploration & production across-group Independent equity return gaps with the fracking revolution increased the most for any Independent sector, either within or across decompositions, indicating that the greatest fracking industry realignment was in equity markets as participants increased upstream exploration & production returns closer to oil and gas extraction.

JEL-Codes: G120, L710, L720, O130, O140, Q400, Q410.

Keywords: New Growth Theory, hydraulic-fracturing, technology, financial, commodity markets and technological change.

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## **Equity, Commodity, and Distillate Returns during Industry Transformation: New Growth in the Oil and Gas Industry**

### **I. Introduction**

Innovation occurs across industry networks, and New Economic Growth Theory integrates knowledge, human capital, ideas, and positive geographic externalities to analyze growth that results from endogenous relationships. The oil and gas industry has various overlapping sectors, where knowledge, human capital, and positive spill-over effects contribute to economic growth. Hydraulic fracking is the process where a liquid propellant—primarily water in a slick-water frack—is forced into a well-bore under high pressure that leads to greater crude and natural gas recovery. After injected material and pressure are reduced, propellants keep fractures open, which allows hydrocarbons encased in deep rock formations to escape, increasing well-productivity (Gold, 2013, pp. 120-125). While early forms of hydraulic fracturing began as early as 1949, by 2013, the majority of wells brought into production are fracked (EIA, 2022). Advanced technologies associated with the fracking revolution include horizontal drilling, hydraulic fracturing, simultaneous fracking, longer lateral wells, 3D seismic imaging, measurement-while-drilling, slim hole drilling, advanced drilling muds, coiled tubing, and improved electric pumps, which allow greater access to previously inaccessible shale formations that dramatically increased oil and gas production (Zimmerman, 2013; Gold, 2013). Subsequently, the oil and gas industry is a leading application of New Growth Theory across industry networks to explain industrial transformation across an industry with interrelated sectors.

Hydraulic fracturing is now prominent in the largest US oil and gas shale formations: the Bakken, Permian, and Eagle Ford shales.<sup>1</sup> While high crude and natural gas prices were common in 2008, 2010, and 2014, innovation in US hydrocarbon markets increased shale production, which decreased prices between 2015 and 2020. Traditional vertical drilling is the process where an oil reserve is vertically accessed from the surface and was the standard drilling method until a large-scale fracking recovery break-through in natural gas by George P. Mitchell in the Barnett Shale, a geological formation in the Ben-Arch-Fort Worth Basin. To increase crude oil production, Harold Hamm implemented crude oil horizontal drilling in the Bakken formation, and non-traditional drilling is now standard in US oil and gas production (EIA, 2022; Gold, 2013; Zuckerman, 2013).

Changes in oil and gas recovery influenced distillates derived from crude. Innovation in the oil and gas industry's upstream production changed access to primary resources to downstream firms that use oil in refined derivatives.<sup>2</sup> The fracking revolution was technical, geographical, and created by engineers, which increased upstream productivity that had spill-over effects with mid-stream and downstream oil and gas producers. By itself, unprocessed oil and gas have limited value, and distillates considered here are conventional gas, diesel, and aviation fuels. Diesel is a heavy grade distillate used in ground freight, manufacturing, and rail transportation. Conventional gas is used to transport automobiles and other mobile platforms. Aviation fuels are high octane derivatives used in the aviation industry, and about 10 percent of refined oil is aviation fuels.

It is against that backdrop that this study considers the fracking revolution's effect on smaller upstream, midstream, and downstream producers compared to large Integrated firms. Two questions are considered. First, how did upstream, midstream, and downstream risks vary by equity,

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<sup>1</sup> The Bakken Shale is in North Dakota. The Permian Basin Shale is in Eastern New Mexico and West Texas. The Eagle-Ford Shale is in South Central Texas.

<sup>2</sup> This study does not address how increased productivity increased criterion pollutants from increased gasoline consumptions.

commodity, and distillate risks within the industry relative to Integrated Majors before and after the fracking revolution? The fracking revolution changed within-group technology that favored Independent firms who outperformed larger Integrated producers. Second, how did upstream, midstream, and downstream returns vary by equity, commodity, and distillate returns across the industry relative to Integrated Majors before and after the fracking revolution? Exploration & production across-group Independent equity return gaps increased the most for any returns gap—either within or across decompositions—indicating that the greatest fracking industry realignment was in equity markets as participants increased upstream exploration & production returns closer to oil and gas extraction.

## II. The United States Oil and Natural Gas Industry

Neo-classical growth theory emphasizes capital per worker, exogenous technology shocks, and capital deepening, emphasizing endogenous innovation, network effects, knowledge, and human capital spillover effects that create new products and processes (Romer, 1996, pp. 95-96, and 111-116). Nordaus (1969, p. 18), Romer (1986), Romer (1991), and Lucas (1988) find that Neoclassical growth theory lacks explanations for new technologies integrated into economic growth and innovation. New growth theory emphasizes new technologies, externalities, and ideas from human capital to explain economic growth. Jaffe (1986) finds that technology and innovation spillovers increase with closer physical proximity, and the North American oil and gas industry had considerable geographic externalities with the 2011-2016 horizontal drilling revolution. Regional oil and gas spillover effects into non-traditional fracking and horizontal drilling techniques vacillated and were developed after repeated failures in Texas' Barnett Shale during the 1980s and 1990s with George P. Mitchell and Mitchell Energy and Development Corporation. After Mitchell's processes were proven successful, horizontal techniques were widely adopted and created a North American natural gas boom (Zukerman, 2013; Gold, 2013).

The oil and gas industry is organized into four sectors. Independents are classified as upstream, midstream, and downstream producers that specialize in distinct sectors based on labor supplies, infrastructure, and technology. Upstream exploration & production and equipment & service firms

explore for and extract oil and natural gas and include Apache,<sup>3</sup> Concho, EOG, Marathon Oil, National Oilwell Varco, Occidental, Pioneer, and Range Resources. Midstream transportation & pipeline firms transport and store oil and gas once brought into production and include Chiniere, Kinder Morgan, OneOK, and Whiting Companies. Downstream end-use refining & marketing firms process and distribute crude and natural gas into distillates, sold into downstream markets and include Holly Frontier, Marathon Petroleum, Targa Resources, and Valero. Vertical integration occurs when a production process is vertically aligned and managerial structures organized into multiple operating units within the same firm. Large well-capitalized Integrated producers vertically combine oil and natural gas production into single operation units previously known as Super Majors, where much of US private sector oil and natural gas is produced, transported, and refined in a single vertically integrated firm, which include BP, Chevron, ConocoPhillips, Exxon, Hess, Royal Dutch Shell, and Total SA. The fracking revolution changed technology that favored Independent firms who outperformed larger Integrated producers (Carson, 2022).

Assessing how the oil and gas fracking revolution realigned the industry in this study is triangulated off industry information signaled in equity, commodity, and distillate markets (Gold, 2013, pp. 198-199). Markowitz (1952) was the first to model a mean-variance explanation for Modern Portfolio Theory, followed by Sharpe (1964), Litner (1965), and Mossin (1966), who extend mean-variance analysis into a single asset pricing model that partitions firm returns into a risk-free rate, risk quantity, and risk premium. However, original asset pricing models are not well supported by the evidence, and Fama and French (1993, 1996, 2004), Jagadeessh and Titman (1993), and Carhart (1997) add factors to improve pricing model's risk evaluation. Assuming equity and commodity markets are sufficiently efficient to price risk into the production process, augmented CAPM models are used here to evaluate market and project risk across upstream, midstream, and downstream sectors relative to Integrated majors.

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<sup>3</sup> As is common in the oil and gas industry, Apache Corporation has been acquired by APA Corporation, which is another exploration & production corporation.



Asset pricing is useful to assess risk in the oil and gas industry, and Manning (1991) demonstrates that British upstream exploration & production firms have greater risk than Integrated firms. Goodwin (1993) evaluates oil price variation with US equity returns around the 1973 oil embargo and finds that oil price variation is positively related to refining & marketing firm returns. Rajigopal (1999) demonstrates that market expectations are associated with oil and gas returns, while Faff and Brailsford (1999) demonstrate the effect that oil price shocks have on the Australian Stock market. Sodarsky (2001) finds similar effects for Canadian firms associated with broader market indices, oil prices, and interest rates. Mohanty and Nandha (2011) use a four-factor type model to show that oil price variation is positively related to equity returns with size, value, and momentum effects. Carson (2020) evaluates Major and Independent oil and gas returns, and Independents have greater return variation than large Integrated firms that bear less risk because they have more secure labor supplies and easier access to capital. Carson (2022) partitions the oil and gas industry into Majors and Independents and finds that Integrated Majors had greater access to dependable labor and capital reserves benefited more than Independents, and risk varies across the industry. Subsequently, the oil and gas industry allocates risk across sectors, and throughout the oil and gas industry, asset pricing models are useful to assess risk variation with the fracking revolution.

### **III. Data**

Evaluating Integrated and Independent returns and standard deviations before and after the fracking revolution isolates risks associated with the horizontal drilling and non-traditional recovery methods, and different parts of the oil and gas industry were asymmetrically affected by the fracking revolution. For example, fracking more directly affects upstream exploration & production related to oil and gas recovery and less for downstream refining & marketing. While non-traditional oil and gas techniques have existed for several decades, innovations during the early 2000s is one area to evaluate external innovation effects on firm risk in different industrial sectors.

Data to evaluate oil and gas industry risk realignment with the fracking revolution are from 2000 to 2020. Trade publications and industry experts were consulted to appropriately classify firms in the industry. There are 22 firms in the exploration & production sector, 11 in the equipment & service sector, five firms in the transportation & pipeline sector, and five firms in the refining sector in the data used here. There are 11 Integrated firms. Daily S&P returns are the measure for equity return variation, and daily Brent measures are used for commodity returns. Daily natural gas returns are from Henry Hub, conventional gas, diesel, and aviation fuel are distillate returns that augment commodity market returns. Conventional gas returns are the rate of return on Gulf Coast conventional gas. Diesel returns are the US Gulf Coast ultra-low sulfur, No. 2 diesel fuel. Aviation fuel returns are the Kerosene-type US Gulf Coast rate of return. Daily small-minus-big ( $SMB_t$ ), high-minus-low ( $HML_t$ ), robust-minus-weak ( $RMW_t$ ), conservative-minus-aggressive ( $CMA_t$ ), and momentum ( $MOM_t$ ) factor returns are also included.

Of itself, the fracking revolution changed engineering and physical processes for crude and natural gas extraction. A sizable amount of the fracking transformation occurred between 2013 and 2014, and by 2015, many fracking gains were integrated into firm values associated with equity, commodity, and distillate markets. Subsequently, the pre-fracking period in this study is from 2000 to 2012. The fracking transformation is between 2013 and 2014 (Wethe, 2019), which provides a distinct break for the assimilation and adaption for pre and post fracking technologies into the oil and gas industry. The post-fracking period is after 2014.

**Table 1, Exploration & Production Pre and Post Expected Returns and Standard Deviations**

	<i>Pre-Frack</i>				<i>Post-Frack</i>				<i>Differences</i>		
	N	Mean	S.D.	Sharpe	N	Mean	S.D.	Sharpe	Mean	S.D.	Sharpe
<b>ENP</b>											
Cabot	1,430	.001352	.033676	.0402	1,672	-.000120	.023334	-.0051	-.0015	-.0103	-.0453
Callon	1,386	.000939	.05908	.0159	1,661	.000146	.054459	.0027	-.0008	-.0046	-.0132
Canadian Natural Resources	1,386	.000809	.033096	.0244	1,661	.000188	.027691	.0068	-.0006	-.0054	-.0177
Cimirex	1,386	.000738	.029273	.0252	1,722	-.000077	.030926	-.0025	-.0008	.0017	-.0277
CNX	1,386	.000771	.041243	.0187	1,661	.000075	.037699	.0020	-.0007	-.0035	-.0167
Concho	1,104	.002525	.038713	.0652	1,661	-.000068	.027526	-.0025	-.0026	-.0112	-.0677
Continental	1,160	.002330	.045509	.0512	1,722	.000136	.039946	.0034	-.0022	-.0056	-.0478
Devon	1,430	.000534	.026980	.0198	1,611	-.000472	.033129	-.0143	-.0010	.0062	-.0340
EOG	1,386	.000709	.029261	.0242	1,722	.000076	.025834	.0029	-.0006	-.0034	-.0213
EQT	1,430	.000673	.025756	.0261	1,611	-.000327	.030520	-.0107	-.0010	.0048	-.0368
Equinor	1,386	.000470	.028043	.0168	1,722	.000200	.021935	.0091	-.0003	-.0061	-.0076
Marathon Oil	1,430	.000732	.028735	.0255	1,611	-.000477	.034093	-.0140	-.0012	.0054	-.0395
Noble	1,386	.000323	.030861	.0105	1,660	-.001975	.070059	-.0282	-.0023	.0392	-.0387
Occidental	1,430	.000927	.027957	.0332	1,611	-.000606	.028616	-.0021	-.0015	.0007	-.0543
Ovintiv	1,386	.000124	.026460	.0047	1,661	-.000145	.042129	-.0034	-.0003	.0157	-.0081
Pioneer	1,386	.001092	.033278	.0328	1,661	.000037	.027092	.0014	-.0011	-.0062	-.0315
Range	1,430	.001164	.032777	.0355	1,611	-.000800	.037970	-.0211	-.0020	.0052	-.0566
SMEnergy	1,430	.001019	.033619	.0303	1,611	-.000423	.056786	-.0075	-.0014	.0232	-.0378
SouthWestern	1,430	.001128	.035863	.0315	1,611	-.000947	.039338	-.0241	-.0021	.0035	-.0556
Vaalco	1,430	.000690	.039614	.0174	1,611	.000001	.046853	2.13 <sup>-5</sup>	-.0007	.0072	-.0174
W&T Offshore	1,386	.000540	.040956	.0132	1,661	-.000031	.048257	-.0006	-.0006	.0073	-.0138
Total	1,381	.000933	.034321	.0268	1,654	-.000267	.049606	-.0060	-.0012	.0029	-.0328

Source: <https://finance.yahoo.com/>

**Table 2, Equipment & Services Pre and Post Expected Returns and Standard Deviations**

<i>ENS</i>	<i>Pre-Frack</i>				<i>Post-Frack</i>				<i>Differences</i>		
	N	Mean	S.D.	Sharpe	N	Mean	S.D.	Sharpe	Mean	S.D.	Sharpe
Baker Hughes	1,386	.000083	.031685	.0317	1,661	-.000031	.025211	-.0012	-.0001	-.0065	-.0039
Fluor	1,386	.000571	.032136	.03214	1,661	-.000629	.035563	-.0177	-.0012	.0034	-.0355
Halliburton	1,430	.000411	.030527	.0305	1,611	-.000282	.028734	-.0098	-.0007	-.0018	-.0233
Helmerich & Payne	1,430	.001012	.033241	.0332	1,611	-.000391	.031310	-.0125	-.0014	-.0019	-.0429
Nabors	1,430	.000214	.034279	.0343	1,611	-.000533	.053602	-.0099	-.0008	.0193	-.0162
National Oilwell	1,430	.001309	.036701	.0367	1,611	-.000621	.028262	-.0220	-.0019	-.0084	-.0576
Varco											
Precision Drilling	1,430	.000159	.036307	.0363	1,611	-.000785	.041682	-.0188	-.0009	.0054	-.0232
Schlumberger	1,430	.000560	.028219	.0282	1,611	-.000586	.023032	-.0254	-.0012	-.0052	-.0453
TechnipFMC	1,386	.00139	.031895	.0319	1,661	-.000642	.027821	-.0231	-.0020	-.0041	-.0667
Tidewater	1,386	.000381	.025625	.0256	1,661	-.002092	.048786	-.0429	-.0025	.0232	-.0578
Total	1,412	.00061	.03206	.0189	1,631	-.000660	.034400	-.1834	-.0013	.0023	-.0372

Source: <https://finance.yahoo.com/>

**Table 3, Integrated Pre and Post Expected Returns and Standard Deviations**

	<i>Pre-Frack</i>				<i>Post-Frack</i>				<i>Differences</i>		
	N	Mean	S.D.	Sharpe	N	Mean	S.D.	Sharpe	Mean	S.D.	Sharpe
BP	1,430	.000128	.022583	.0226	1,611	-.000085	.019215	-.0044	-.0002	-.0034	-.0100
Chevron	1,430	.000699	.020310	.0203	1,611	.000137	.018937	.0072	.0072	-.0014	-.0272
ConocoPhillips	1,386	.000244	.024001	.0240	1,661	-.000025	.019073	-.0013	-.0013	-.0049	-.0115
ENI	1,386	.000246	.023253	.0233	1,661	-.000162	.018952	-.0086	-.0086	-.0043	-.0191
Exxon	1,386	.000476	.019105	.0191	1,661	-.000305	.015813	-.0193	-.0193	-.0033	-.0442
Hess	1,386	.000663	.032405	.0324	1,661	.000095	.028154	.0038	.0034	-.0043	-.0171
Murphy	1,386	.000552	.027288	.0273	1,661	-.000131	.034923	-.0038	-.0035	.0076	-.0240
Petrobras	1,386	.000835	.034762	.0348	1,722	.000556	.037624	.0148	.0148	.0029	-.0092
PetroChina	1,386	.000665	.028886	.0289	1,661	-.000405	.019808	-.0205	-.0205	-.0091	-.0435
Royal Dutch Shell	1,385	.000465	.021627	.0216	1,661	-.000158	.020251	-.0078	-.0078	-.0014	-.0293
Total, SA	1,430	.000310	.022069	.02207	1,611	.000085	.018524	.0046	.0046	-.0036	-.0095
Total	1,398	.000480	.025120	.01900	1,653	-.000030	.022843	-.0032	-.0034	-.0023	-.0222

Source: <https://finance.yahoo.com/>

**Table 4, Transportation & Pipeline and Refining & Marketing Expected Returns and Standard Deviations**

	<i>Pre-Frack</i>				<i>Post-Frack</i>				<i>Differences</i>		
<b>TNP</b>	N	Mean	S.D.	Sharpe	N	Mean	S.D.	Sharpe	Mean	S.D.	Sharpe
Cheniere	1,386	.000961	.065391	.0147	1,661	.000366	.023578	.0155	-.0006	-.0418	.0008
Kinder Morgan	217	.000403	.017810	.0226	1,721	-.000128	.021544	-.0059	-.0005	.0037	-.0286
OneOK	1,430	.000941	.021203	.0444	1,611	.002094	.029448	.0711	.0012	.0083	.0267
Whiting Companies	1,386	.001386	.039255	.0353	1,661	-.000746	.081917	-.0091	-.0021	.0427	-.0444
Total	1,105	.000923	.035915	.0293	1,664	.000397	.039122	.0179	-.0005	.0032	-.0114
<b>RNM</b>											
Holly Frontier	1,430	.001020	.035185	.0290	1,611	.000091	.027006	.0034	-.00093	-.0082	-.0256
Marathon Petroleum	128	-.000219	.038058	-.0058	1,611	.000504	.027079	.0186	.0007	-.0110	.0244
Targa Resources	264	.002100	.022451	.0935	1,611	.000052	.037784	.0014	-.0021	.0153	-.0922
Valero	1,430	-.000105	.031236	-.0034	1,611	.000413	.023776	.0174	.0005	-.0075	.0207
Total	813	.0007	.031733	.0284	1,611	.000265	.028911	.0102	-.0004	-.0028	-.0182

Source: <https://finance.yahoo.com/>

### *Pre-Fracking*

Exploration & production had the highest pre-fracking average return, followed by transportation & pipeline, refining & marketing, equipment & services, and Integrated firms (Tables 1 through 4).

Upstream exploration & production is historically a high-risk sector with greater returns to compensate for greater risk. Nonetheless, downstream transportation & pipeline and refining & marketing firms had considerable risk with distillate and fuels, where because of order flow and infrastructure, transportation & pipeline and refining & marketing bear risk when they purchase raw crude in commodity markets and face uncertainty when crude prices fluctuate before refined product is delivered to output markets (Carson, 2020; Carson, 2022a; Carson, 2022b; Peltzman, 2000). Prior to the fracking revolution, equipment & services and Integrated firms had lower equity returns. Equipment & services face the greatest competitive pressure from Independent rivals, associated with lower equipment & service profitability. On the other hand, well-capitalized large pre-fracking Integrated firms had the lowest expected risk and returns within the industry.

Sharpe ratios are expected returns divided by standard deviations and are a measure for returns per unit of risk (Tables 1 through 4). Although pre-fracking risk was high in transportation & pipeline, financial markets rewarded transportation & pipeline firms with the highest return relative to risk. In the pre-fracking period, refining & marketing firms were similarly compensated for risk, indicating that midstream and downstream pre-fracking risk was rewarded more than upstream risk. Large Integrated firms, with greater time in the industry and liquidity, had the lowest Sharpe Ratios, indicating their access to capital, and infrastructure were the least rewarded in the industry.

### *Post-Fracking*

Across the oil and gas industry, returns were lower after the fracking revolution as upstream exploration & production and equipment & service sector firms brought greater crude into production that decreased returns. In part, oil, natural gas, and distillates extraction changed comparative risk and sector compensations. Transportation & pipeline had the highest post-fracking average returns, followed by refining & marketing, Integrated, exploration & production. Increased international oil and gas supplies

decreased exploration & production and equipment & service returns, and their post-fracking risk was highest in the industry when they faced greater supplies and risk with purchase-delivery risk in transportation & pipeline. Post-fracking downstream firm returns were high because supply disruptions associated with asymmetric delivery times, when Covid 2020 squeezed transportation & pipeline and refining & marketing firms were caught in the middle of upstream and downstream capacity asymmetries that increased transportation & pipeline risk that was compensated with greater returns. Large well-capitalized Integrated firms had the lowest post fracking risk, followed by refining & marketing who took crude delivery without facing comparable risk associated with asymmetric purchase-delivery risk in transportation & pipeline. Integrated and upstream exploration & production and equipment & services returns per unit of risk were lower after the fracking revolution.

#### *Changes in Returns per Unit of Risk*

Refining & marketing returns increased the most with the fracking revolution, followed by transportation & pipeline, exploration & production, equipment & services, and Integrated firms. With asymmetric purchase and delivery times, transportation & pipeline risk increased the most with fracking, followed by exploration & production, equipment & services, Integrated, and refining & marketing. Among the complex risk-return fracking revolution realignments, return increases per unit of risk were highest among transportation & pipeline and refining & marketing, indicating that downstream and midstream producers were better off with the fracking revolution. Integrated returns-per-unit of risk was next most rewarded, while increased oil production decreased upstream exploration & production and equipment & service returns the least relative to risk with the fracking revolution.

#### **IV. Independent and Integrated Return Variation by Equity, Commodity, and Distillate Markets**

Decomposing Independent and Integrated equity, commodity, and distillate market risk before and after the fracking revolution offers insight into New Economic Growth Theory's explanation for



innovation and spatial effects in the oil and gas industry. The oil and gas industry data are partitioned into the  $j^{\text{th}}$  pre and post fracking periods and regressed on the  $i^{\text{th}}$  firm's equity return in the  $j^{\text{th}}$  period.

$$\begin{aligned} (R_{it} - R_{ft})_t^j = & \alpha_0^j + \beta_1^j (R_{mt} - R_{ft})^j + \beta_2^j (R_{ot} - R_{ft})^j + \beta_3^j (R_{gt} - R_{ft})^j + \beta_4^j (R_{ct} - R_{ft}) + \beta_5^j (R_{dt} - R_{ft}) \\ & + \beta_6^j (R_{at} - R_{ft}) + \beta_7 SMB_t^j + \beta_8 HML_t^j + \beta_9 RMW_t + \beta_{10} CMA_t + \beta_{11} MOM_t^j + \varepsilon_t^j \quad (\text{Equation 1}) \end{aligned}$$

$R_{it}$  is the  $i^{\text{th}}$  firm's daily return.  $R_{ft}$  is the daily risk-free three-month US T-Bill rate. Over the interval, the treasury's T-Bill rate was low and stable, yet varied with the 2008 financial crisis.  $\beta_1^j$  is S&P 500 return sensitivity to variation in the  $j^{\text{th}}$  period and is the primary source of equity market variation.  $R_{ot}$  is the daily Brent Crude rate of return, and  $\beta_2$  is the Brent crude oil sensitivity return parameters in the  $j^{\text{th}}$  period.  $R_{gt}$  is the natural gas daily rate of return for natural gas prices at Henry Hub, and  $\beta_3$  is the natural gas excess return sensitivity parameter in the  $j^{\text{th}}$  period.  $R_{cg}$  is the daily rate of return on conventional gas measured at Erath, Louisiana, and  $\beta_4$  the conventional gas sensitivity parameter in the  $j^{\text{th}}$  period.  $R_d$  is the diesel daily rate of return measured on low sulfur no. 2 in the Gulf Coast, and  $\beta_5$  is the diesel sensitivity parameter.  $R_{jt}$  is each firm's daily rate of return with aviation fuel, and  $\beta_6$  is the aviation fuel excess return sensitivity parameter in the  $j^{\text{th}}$  period.  $\beta_7, \beta_8, \beta_9, \beta_{10},$  and  $\beta_{12}$  are firm excess return variation with  $SMB_t, HML_t, RMW_t, CMA_t$  and  $MOM_t$ . In the results that follow, Independent and Integrated coefficients are estimated with GARCH (1, 1), used to estimate Oaxaca and difference-in-decompositions in the next section (Ng and Lam, 2006).

Table 5, Exploration &amp; Production Pre and Post Generalized Autoregressive Integrated Moving Average Models

	<i>Cabot Oil &amp; Gas</i>		<i>Callon Energy</i>		<i>Canadian Natural Resources</i>		<i>Cimirex</i>		<i>CNX</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	0.001	-0.001	5.89 <sup>-4</sup>	.001*	2.11 <sup>-4</sup>	1.45 <sup>-4</sup>	0.001	-5.14	2.70 <sup>-4</sup>	-0.001
SNP	1.22***	.835***	1.28***	1.31***	1.09***	.961***	1.01***	1.10***	1.59***	1.09***
Crude Oil	.067***	-.066***	.087*	0.035	.122***	.070***	.084***	0.027	0.035	0.005
Natural Gas	.028*	.028***	.034*	0.008	0.007	-0.001	0.016	0.012	0.025	.032***
Conventional Gas	.123***	0.02	0.053	.095**	.089***	.055***	.060***	0.035	.117***	-0.003
Diesel	.241***	.075*	.202***	.248***	.172***	.115***	.135***	.201***	.136**	.120***
Aviation Fuel	-0.002	0.004	0.061	.167***	.123***	.139***	.062**	0.043	.089*	0.061
SMB	.002**	.002*	.013***	0.01	.001**	.002***	.003***	.003***	.003**	.006***
HML	.002**	-0.001	.011***	.012***	0.001	1.69 <sup>-4</sup>	.002**	.004***	0.001	0.002
RMW	.007***	-.007***	-0.001	-.008***	0.002	-.006***	.002*	-.009***	0.005	-.012***
CMA	-.018***	.009***	-.010***	-5.86	-.012***	.008***	-.008***	.005***	-.017***	.008***
MOM	.004***	-.004***	.011***	-.010***	0.002	-.006***	.002***	-.006***	.002**	-.008***
N	1430	1672	1386	1661	1386	1661	1386	1722	1386	1661
	<i>Concho</i>		<i>Continental</i>		<i>Devon</i>		<i>EOG</i>		<i>EQT</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	.002**	2.02 <sup>-4</sup>	0.001	0.001	4.93 <sup>-5</sup>	9.56 <sup>-5</sup>	1.17 <sup>-6</sup>	8.79 <sup>-5</sup>	1.09 <sup>-4</sup>	-.001**
SNP	1.04***	1.07***	1.25***	1.23***	1.05***	1.29***	1.09***	1.03***	1.11***	.861***
Crude Oil	.154***	.066***	.142***	.072***	0.005	.042*	0.002	.061***	.062***	-0.006

Natural Gas	0.006	0.008	0.013	0.005	.031***	0.007	.024***	0.001	.025***	.059***
Conventional Gas	.118***	.046**	0.061	0.044	.060***	0.018	.087***	.047***	0.002	0.023
Diesel	.235**	.233***	.228***	.380***	.164***	.264***	.186***	.193***	.127***	0.082
Aviation Fuel	-0.013	-0.023	0.099	.101***	.058**	0.028	.052*	0.01	0.012	-0.012
SMB	.004***	0.001	.003**	.005***	-7	.002***	9.18 <sup>-6</sup>	.002**	1.07 <sup>-4</sup>	.003***
HML	-8.33	.002*	.003**	.004***	.003***	.004***	0.001	.002***	.002***	0.001
RMW	-0.002	-.010***	0.002	-.012***	.005***	-.013***	.004***	-.008***	.005***	-.006***
CMA	-.010***	.006***	-.012***	.007***	-.011***	.010***	-.016***	.006***	-.006***	.006***
MOM	.002***	-.006***	.003***	-.008***	.003***	-0.008	.003***	-.005***	.002***	-.005***
N	1104	1661	1160	1722	1430	1611	1386	1722	1430	1611

**Note:** \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

**Source:** See Table 1.



Table 5, Exploration &amp; Production Pre and Post Generalized Autoregressive Integrated Moving Average Models

	<i>EQT</i>		<i>Equinor</i>		<i>Marathon Oil</i>		<i>Nobel</i>		<i>Occidental</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	1.09 <sup>-4</sup>	-.001**	-1.97 <sup>-4</sup>	1.30 <sup>-4</sup>	2.56 <sup>-4</sup>	1.13 <sup>-4</sup>	-7.25 <sup>-5</sup>	-.001	2.90 <sup>-4</sup>	-3.32 <sup>-4</sup>
SNP	1.11***	.861***	1.17***	.920***	1.18***	1.37***	1.30***	1.43***	1.17***	.911***
Crude Oil	.062***	-.006	.160***	.087***	.045**	.073***	.058**	.122***	.053***	.031**
Natural Gas	.025***	.059***	-4.39 <sup>-4</sup>	.004	.004	-.002	.004	-.017	-.001	.004
Conventional Gas	.002	.023	.049**	.043***	.078***	.084***	.070***	.141***	.074***	.027**
Diesel	.127***	.082	.129***	.124***	.140***	.286	.171***	.274***	.191***	.156***
Aviation Fuel	.012	-.012	.061*	.062**	.023	.006	.037	-.099*	.027	.014
SMB	1.07 <sup>-4</sup>	.003***	6.25 <sup>-5</sup>	-.002***	-.002	.002*	1.76 <sup>-4</sup>	.003**	-.001	9.19 <sup>-5</sup>
HML	.002***	.001	.001	.001	2.51 <sup>-4</sup>	.003***	-4.39 <sup>-5</sup>	.002	.001	3.98 <sup>-4</sup>
RMW	.005***	-.006***	.003***	-.006***	.003**	-.014***	.005***	-.015***	.004***	-.004***
CMA	-.006***	.006***	-.004***	.007***	-.007***	.013***	-.017***	.019***	-.012***	.008***
MOM	.002***	-.005***	.002***	-.004***	-9.36 <sup>-5</sup>	-.008***	.003***	-.013***	.002***	-.004***
N	1,430	1,611	1,386	1,722	1,430	1,611	1,386	1,660	1,430	1,611
	<i>Ovintiv</i>		<i>Pioneer</i>		<i>Range</i>		<i>SM Energy</i>		<i>Ovintiv</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	-3.05 <sup>-4</sup>	4.05 <sup>-5</sup>	.001*	6.59 <sup>-5</sup>	.001	-.002**	3.73 <sup>-4</sup>	8.99 <sup>-5</sup>	Intercept	-3.05 <sup>-4</sup>
SNP	.921***	1.01***	1.14***	1.09***	1.14***	1.07***	1.05***	1.44***	SNP	.921***
Crude Oil	.094***	.003	.103***	.029*	.064**	-.048	.121***	.172***	Crude Oil	.094***
Natural Gas	.037***	.020	.018*	.004	.031***	.089***	.041***	.023	Natural Gas	.037***
Conventional Gas	.084***	.082***	.092***	.043**	.115***	.003	.095***	.052	Conventional Gas	.084***
Diesel	.152***	.319***	.215***	.180***	.138***	.233***	.200**	.550***	Diesel	.152***
Aviation Fuel	.045*	.146***	.016	.012	.054	.011	.030	.025	Aviation Fuel	.045*
SMB	.001**	.005***	.002***	.002**	.005***	.007***	.004***	.007***	SMB	.001**
HML	.001*	.003***	.004***	.002**	.003***	.002	.002*	.005***	HML	.001*

RMW	.003***	-.012***	.003**	-.009***	.008***	-.010***	.001	-.017***	RMW	.003***
CMA	-.010***	.012***	-.013***	.007***	-.023***	.007***	-.009***	.006**	CMA	-.010***
MOM	.002	-.008***	.003***	-.005***	.004***	-.010***	.003***	-.015***	MOM	.002
N	1,386	1,661	1,386	1,661	1,430	1,611	1,430	1,611	N	1,386

**Note:** \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

**Source:** See Table 1.

Table 5, Exploration &amp; Production Pre and Post Generalized Autoregressive Integrated Moving Average Models

	<i>Ovintiv</i>		<i>Pioneer</i>		<i>Range</i>		<i>SM Energy</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	-3.05 <sup>-4</sup>	4.05 <sup>-5</sup>	.001*	6.59 <sup>-5</sup>	.001	-.002**	3.73 <sup>-4</sup>	8.99 <sup>-5</sup>
SNP	.921***	1.01***	1.14***	1.09***	1.14***	1.07***	1.05***	1.44***
Crude Oil	.094***	.003	.103***	.029*	.064**	-.048	.121***	.172***
Natural Gas	.037***	.020	.018*	.004	.031***	.089***	.041***	.023
Conventional Gas	.084***	.082***	.092***	.043**	.115***	.003	.095***	.052
Diesel	.152***	.319***	.215***	.180***	.138***	.233***	.200**	.550***
Aviation Fuel	.045*	.146***	.016	.012	.054	.011	.030	.025
SMB	.001**	.005***	.002***	.002**	.005***	.007***	.004***	.007***
HML	.001*	.003***	.004***	.002**	.003***	.002	.002*	.005***
RMW	.003***	-.012***	.003**	-.009***	.008***	-.010***	.001	-.017***
CMA	-.010***	.012***	-.013***	.007***	-.023***	.007***	-.009***	.006**
MOM	.002	-.008***	.003***	-.005***	.004***	-.010***	.003***	-.015***
N	1,386	1,661	1,386	1,661	1,430	1,611	1,430	1,611
	<i>Southwestern</i>		<i>Vaalco</i>		<i>W&amp;T Offshore</i>		<i>Average</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	1.92 <sup>-4</sup>	-.002***	-2.03 <sup>-4</sup>	-2.44 <sup>-4</sup>	2.13 <sup>-4</sup>	-5.11 <sup>-5</sup>	.001	-2.35 <sup>-4</sup>
SNP	1.20***	1.11***	1.18***	.758***	1.15***	1.14***	1.22	1.16
Crude Oil	.018	-.046	-.019	-.044	.100***	.228***	.081	.047
Natural Gas	.064***	.100***	.019	.017	.013	.015	.022	.020
Conventional Gas	.098***	-.012	.055	.077**	.095**	.043	.083	.048
Diesel	.144***	.125**	.167***	.307***	.289***	.449***	.190	.252
Aviation Fuel	.079**	.084	.080*	.097	-.019	-.037	.051	.045
SMB	.002**	.006***	.011***	.002	.011***	.012***	.003	.004
HML	.002	.003**	.001	-.002	.005***	.002	.002	.003
RMW	.007***	-.013***	.001	-.009***	.003	-.012***	.003	-.011
CMA	-.022***	.009***	-.017***	.002	-.017***	.001	-.013	.008

MOM	.004***	-.011***	.003***	-.008***	.003***	-.010***	.003	-.008
N	1,430	1,611	1,430	1,611	1,386	1,661		

**Note:** \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

**Source:** See Table 1.



Table 6, Equipment &amp; Services Pre and Post Generalized Autoregressive Integrated Moving Average Models

	<i>Baker Hughes</i>		<i>Fluor</i>		<i>Halliburton</i>		<i>Helmerich &amp; Payne</i>		<i>Nabors Drilling</i>		<i>National Oilwell Varco</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	-.001	9.66 <sup>-5</sup>	.001	.001* **	-6.87 <sup>-5</sup>	-2.40 <sub>3</sub>	.001	-7.06 <sub>5</sub>	-1.56 <sup>-4</sup>	-3.94 <sub>5</sub>	.001*	-2.90 <sup>-4</sup>
SNP	1.22** *	1.05* **	1.36***	1.07* **	1.15***	1.17* **	1.28***	1.06* **	1.21* **	1.44* **	1.46***	1.07** *
Crude Oil	.056**	.011	.034	.017* **	.065***	.080* **	.049**	.067* **	.030	.126* **	.041	.071** *
Natural Gas	.016	.003	.009	.029* **	.003	.001	.024***	-.002	.036* **	.011	.012	.012
Conventional Gas	.094** *	.048* *	.017	- .173* **	.086***	.020	.079***	.077* **	.071* *	.074* *	.093***	.021
Diesel	.198** *	.083* *	-.010	.125* **	.174***	.174* **	.195***	.125* **	.208* **	.265* **	.187***	.067
Aviation Fuel	-.010	.040	.113***	.038	.036	.006	.015	.076* *	.075* *	.070	.077**	.042
SMB	.004** *	.001	.004***	.007* **	.003***	.002* **	.004***	.003* **	.004* **	.008* **	.001	.004** *
HML	.001	.002* **	-.002**	.001*	-.001	.003* **	.003***	.004* **	.001	.006* **	-3.19 <sup>-4</sup>	.005** *
RMW	.003**	- .007* **	-.004***	- .002* **	-.001	- .006* **	.004***	- .010* **	-.003*	- .016* **	.001	- .010** *
CMA	- .006** *	.009* **	-.009***	.004* **	-.012***	.007* **	- .019***	.009* **	- .011* **	.018* **	-.017***	.006** *

MOM	.003** *	- .005* **	.002***	- .005* **	.004	- .006* **	.003***	- .008* **	.002* **	- .012* **	.003***	- .006* **
N	1,386	1,661	1,386	1,661	1,430	1,611	1,430	1,611	1,430	1,611	1,430	1,611
	<i>Precisi on Drillin g</i>		<i>Schlumber ger</i>		<i>TechnipF MC</i>		<i>Tidewat er</i>		<i>Avera ge</i>			
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack		
Intercept	-1.51 <sup>-6</sup>	-1.16 <sup>-4</sup>	1.17 <sup>-4</sup>	-.001*	.001**	-3.15 <sup>-4</sup>	-1.27	-.001	1.89 <sup>-4</sup>	-3.73 <sup>-4</sup>		
SNP	1.24** *	1.33* **	1.21***	1.00* **	1.26***	1.08* **	.986***	1.01* **	1.24	1.13		
Crude Oil	.013	.117* **	.056**	.061* **	.037	.039* *	-.015	.019	.040	.061		
Natural Gas	.031** *	-.001	.008	.014* *	.003	-1.20 <sup>-4</sup>	.013	- .030* *	.012	.004		
Conventio nal Gas	.075** *	.068* *	.096***	.054* **	.076***	.057* **	.092***	.043	.073	.029		
Diesel	.225** *	.182* **	.136***	.104* **	.102***	.075* *	.168***	.048	.146	.125		
Aviation Fuel	.053	.092	.049**	-.004	.086***	.023	.009	.145*	.064	.053		
SMB	.004** *	.006* **	.002***	.001*	.004***	.002* **	.002***	.007* **	.004	.004		
HML	.003**	.005* **	1.94 <sup>-4</sup>	.004* **	.002**	.004* **	-2.36 <sup>-4</sup>	.005* **	.001	.004		
RMW	.002	- .009* **	.002*	- .005* **	.003**	- .009* **	.003**	- .011* **	-4.00 <sup>-4</sup>	-.009		
CMA	- .016** *	.010* **	-.012***	.005* **	-.012***	.005* **	-.009	.004	-.011	.008		

MOM	.003** *	- .009* **	.001***	- .005* **	.004***	- .007* **	4.04 <sup>-4</sup>	- .013* **	.001	-.008
N	1,430	1,611	1,430	1,611	1,386	1,611	1,386	1,661		

**Note:** \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

**Source:** See Table 2.

Table 7, Integrated Pre and Post Generalized Autoregressive Integrated Moving Average Models

	<i>BP</i>		<i>Chevron</i>		<i>ConocoPhillips</i>		<i>ENI</i>		<i>Exxon</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	-8.04 <sup>-5</sup>	-1.22 <sup>-4</sup>	2.37 <sup>-4</sup>	-1.96 <sup>-4</sup>	2.35 <sup>-4</sup>	8.88 <sup>-5</sup>	-1.77 <sup>-4</sup>	-2.70 <sup>-4</sup>	-4.10 <sup>-5</sup>	-2.98 <sup>-4</sup>
SNP	.918***	.859***	1.03***	.972***	1.03***	.993***	1.16***	.871***	1.04***	.876***
Crude Oil	.072***	.075***	.014	.024**	.049***	.072***	.079***	.050***	.031***	-.003
Natural Gas	-.007	-.003	1.55 <sup>-4</sup>	.001	-.005	-.005	.003	-.005	.002	.001
Conventional Gas	.029*	.042***	.015	.041***	.055***	.050***	.010	.029**	.004	.020**
Diesel	.137***	.111***	.110***	.082***	.102***	.178***	.083***	.064***	.088	.056***
Aviation Fuel	-.026	.001	.028**	-.012	.031	.024	.015	.040*	3.48 <sup>-5</sup>	.031*
SMB	-.001*	-.001*	-.003***	-.002***	-.002***	.001	-.002***	1.56 <sup>-5</sup>	-.003255	-.002***
HML	-.001**	.002***	-5.75 <sup>-5</sup>	.003***	.002***	.004***	-2.69 <sup>-4</sup>	.002***	-.000770	.002***
RMW	1.72 <sup>-4</sup>	-.005***	.004***	-.005***	.006***	-.007***	-.001	-.004***	.006391	-.003***
CMA	-.002**	.006***	-.003***	.007***	-.002**	.010***	.003**	.006***	3.65 <sup>-4</sup>	.005***
MOM	.001***	-.003***	.002***	-.002***	.002***	-.004	.003***	-.002***	.002***	-.003***
N	1,430	1,611	1,430	1,611	1,386	1,661	1,386	1,661	1,386	1,661
	<i>HES</i>		<i>Murphy Oil</i>		<i>Petrobras</i>		<i>PetroChina</i>		<i>Royal Dutch Shell</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	2.13 <sup>-5</sup>	2.84 <sup>-4</sup>	.002	-.004	-3.57 <sup>-4</sup>	.001	4.86 <sup>-5</sup>	-7.06 <sup>-4</sup>	1.73 <sup>-4</sup>	-1.48 <sup>-4</sup>
SNP	1.29***	1.18***	1.10***	1.14***	1.32***	1.33***	1.13***	.935***	1.01***	.807***
Crude Oil	.025	.081***	.079***	.054**	.092***	.063**	.063***	.041***	.076***	.081***
Natural Gas	.017*	.001	.007	.007	-.028***	.008	-.003	4.76 <sup>-7</sup>	-.006	-.006
Conventional Gas	.119***	.061***	.087***	.083***	.113***	.026	.026	-.004	.011	.039***
Diesel	.129***	.244***	.135***	.299***	.044	.189***	.064***	.155***	.105***	.147***
Aviation Fuel	.065**	-.015	.065**	.070**	.083**	.073	.022	.010	.010	-.031
SMB	-1.70 <sup>-4</sup>	.001	4.36 <sup>-4</sup>	.006***	.001	-.002*	-2.26 <sup>-5</sup>	-4.65 <sup>-4</sup>	-.002***	-.001
HML	.001	.002**	-.001	.007***	5.23 <sup>-5</sup>	.002	.002***	-1.91 <sup>-5</sup>	-.001*	.002***

RMW	.003**	-.010***	.003***	-.008***	.005***	-.008***	.004***	-.004***	.001	-.004***
CMA	-.003**	.016***	-.001	.021***	-.010***	.011***	-.005***	.002**	-.001	.006***
MOM	.002***	-.006***	-7.34 <sup>-7</sup>	1.06 <sup>-6</sup>	7.63 <sup>-5</sup>	-.005***	7.76 <sup>-5</sup>	-.003***	.002***	-.002***
N	1,386	1,661	1,386	1,661	1,386	1,722	1,386	1,661	1,385	1,661

Note: \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

Source: See Table 3.

**Table 7, Integrated Pre and Post Generalized Autoregressive Integrated Moving Average Models**

	<i>Total</i>		<i>Average</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	-1.93 <sup>-4</sup>	-1.85 <sup>-4</sup>	1.71 <sup>-4</sup>	-3.77 <sup>-4</sup>
SNP	1.15***	.888***	1.11	.914
Crude Oil	.082***	.051***	.060	.054
Natural Gas	-.001	1.37 <sup>-4</sup>	-.002	-7.84 <sup>-5</sup>
Conventional Gas	.026**	.042***	.045	.039
Diesel	.104***	.087***	.097	.147
Aviation Fuel	-.001	.022	.027	.019
SMB	-.001***	-.001***	.003	-1.20 <sup>-4</sup>
HML	-4.40 <sup>-4</sup>	.002***	4.69 <sup>-5</sup>	.003
RMW	.001	-.003***	.003	-.006
CMA	-.002	.004***	-.002	.009
MOM	.002***	-.003***	.002	-.003
N	1,430	1,661		

**Note:** \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

**Source:** See Table 3.

**Table 8, Transportation & Pipeline Pre and Post Generalized Autoregressive Integrated Moving Average Models**

	<i>Cheniere</i>		<i>Kinder Morgan</i>		<i>OneOK</i>		<i>Whiting</i>		<i>Average</i>	
	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack	Pre-Frack	Post-Frack
Intercept	.001	3.47 <sup>-4</sup>	.001	-1.27 <sup>-4</sup>	.001**	.001	.001*	-4.28 <sup>-4</sup>	.001	1.48 <sup>-4</sup>
SNP	.727***	.984***	.558***	.904***	.888***	.968***	1.24***	1.91***	.853	1.26
Crude Oil	-.001	-.026	-.103	.009	.026*	.030*	.125***	.108***	.012	.049
Natural Gas	-.014	.003	.018	.007	.013**	.010	.015	-.006	.008	.004
Conventional Gas	.051	.030	-.074	.029**	.047***	.015	.145***	.079*	.042	.041
Diesel	.068	.127***	.161	.077***	.029	.158***	.227***	.654***	.121	.296
Aviation Fuel	.129	.029	-.046	-.023	-.006	.032	-.070	.082	.002	.030
SMB	.011	.002***	-.002	.001	.002***	.001**	.007***	.013***	.005	.005
HML	.005	-.001	.007**	.001	.002***	-.001	.003***	6.88 <sup>-5</sup>	.004	2.29 <sup>-5</sup>
RMW	-.007**	-.010***	-.006	-.008***	.005***	-.006***	.003*	-.013***	-.001	-.009
CMA	-.010***	.005***	-.013**	.006***	.002**	.009***	-.018***	.021***	-.010	.012
MOM	.003*	-.003***	.009***	-.003***	.002***	-.003***	.003***	-.014***	.004	-.007
N	1,386	1,661	217	1,721	1,430	1,611	1,386	1,611		

Note: \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

Source: See Table 4.

**Table 9, Refining & Marketing Pre and Post Generalized Autoregressive Integrated Moving Average Models**

	<i>Holly Frontier</i>		<i>Marathon Petroleum</i>		<i>Targa Resources</i>		<i>Valero</i>		<i>Average</i>	
	Pre- Frack	Post- Frack	Pre-Frack	Post- Frack	Pre-Frack	Post- Frack	Pre- Frack	Post- Frack	Pre- Frack	Post- Frack
Intercept	.001*	3.64 <sup>-5</sup>	.001	1.31 <sup>-4</sup>	.002*	3.27 <sup>-4</sup>	6.67 <sup>-5</sup>	3.67 <sup>-4</sup>	.001	2.65 <sup>-4</sup>
SNP	1.01***	1.04***	.918***	1.18***	.670***	1.06***	1.12***	1.06***	.930	1.09
Crude Oil	.025	-.022	.102	.038*	.045	.091***	.011	.006	.046	.028
Natural Gas	.009	-.007	-.026	-.009	.006	.001	.013	-.003	.001	-.005
Conventional Gas	.264***	.073***	.199	.072***	.121	.020	.166***	.077***	.188	.061
Diesel	.026	.164***	-.415	.061	-.007	.164***	.101**	.042	-.074	.108
Aviation Fuel	.010	-.041	.374	.008	-.039	.076*	.017	-.034	.091	.002
SMB	.005***	.004***	-.006*	.003***	2.33 <sup>-4</sup>	.002***	.004***	.003***	.001	.003
HML	.003**	.003***	.002	.005***	-.001	3.47 <sup>-4</sup>	.001	.004***	.001	.003
RMW	.002	-.002	-.024***	-.001	-.008*	-.009***	-2.31 <sup>-4</sup>	3.93 <sup>-4</sup>	-.008	-.003
CMA	-.009***	-2.52 <sup>-4</sup>	-.006	-.003**	3.91 <sup>-4</sup>	.008***	-.009***	-.002*	-.006	.001
MOM	.002***	-.002***	.010**	-.002***	.004**	-.007***	.001	-.001*	.007	-.003
N	1,430	1,661	128	1,661	264	1,661	1,430	1,661		

**Note:** \*\*\* Significant at .01; \*\* Significant at .05; Significant at .10.

**Source:** See Table 4.



Assessing the oil and gas industry risk in upstream, midstream, and downstream sectors, Tables 5 through 9 present pre and post return generating models, where CAPM-based models' equity, commodity, and distillate returns are risk estimates in upstream, midstream, and downstream sectors. Integrated and partitioned Independent's excess return variation are positively related to equity, commodity, and distillate excess return variation (Tables 5 through 9; Gold, 2013, pp. 198-199). Across upstream, mid-stream, and downstream sectors, Independent equity risk premium are greater than Integrated firms. Equity and commodity risk mostly decreased in the upstream exploration & production, equipment & service, and Integrated industry sectors (Tables 5 through 9). Results are mixed for downstream transportation & pipeline and refining & market, where equity market increased. Nonetheless, concern is risk and return variation and their variation across oil and gas sectors with the fracking revolution.

## **V. Difference-in-Decompositions Model**

Oaxaca-Blinder decompositions (1973) are statistical techniques that partition dependent variable differences into structure and composition effects. To isolate causal effects in the experimental design literatures, Card and Krueger (1993) introduced difference-in-difference estimators that are now standard causal inference techniques using only observational data. A difference-in-decompositions combines Oaxaca-Blinder decompositions and difference-in-difference estimates to separate Independent and Integrated equity, commodity, and distillate risk into structural and compositional effects before and after the unconventional drilling and hydraulic fracturing revolutions. Carson (2018, 2019, 2021, 2022) introduces differences-in-decompositions, while Carson (2022a) uses differences-in-decompositions to the oil and gas industry.

### **5.1 Model**

Within and across Independent and Integrated differences-in-decompositions are constructed before and after the development of unconventional recovery techniques (Tables 5 through 9). Linear

return vector model coefficients are presented in Tables 3 and 4 and expressed as returns to characteristics and returns to average characteristics before and after fracking.  $R_m$  and  $R_i$  are returns to Integrated and Independent oil producers.

Model 1

$$R_m^{pre} = \alpha_m^{pre} + \beta_m^{pre} X_m^{pre} \quad (\text{Equation 2})$$

Model 2

$$R_m^{post} = \alpha_m^{post} + \beta_m^{post} X_m^{post} \quad (\text{Equation 3})$$

Model 3

$$R_i^{pre} = \alpha_i^{pre} + \beta_i^{pre} X_i^{pre} \quad (\text{Equation 4})$$

Model 4

$$R_i^{post} = \alpha_i^{post} + \beta_i^{post} X_i^{post} \quad (\text{Equation 5})$$

where  $\alpha_i^{pre}$  and  $\alpha_m^{pre}$  are Independent and Integrated pre-fracking autonomous return components.  $\beta_i^{pre}$  and  $\beta_m^{pre}$  are Independent and Integrated pre-fracking return sensitivity parameters associated with equity, commodity, and distillate market effects.  $\alpha_i^{post}$  and  $\alpha_m^{post}$  are Independent and Integrated post-fracking autonomous return components.  $\beta_i^{post}$  and  $\beta_m^{post}$  are Independent and Integrated post-fracking sensitivity parameters associated with equity, commodity, and distillate effects. Changes in these post-pre, Independent-Integrated return characteristics are modelled with within-group and across-group difference-in-decompositions. A difference-in-decomposition is different from the difference-in-difference estimator because a difference-in-decomposition is first decomposed with Blinder-Oaxaca decompositions and then differenced, creating differences-in-decompositions that are different from difference-in-difference estimators (Wooldridge, 2010, p. 410). However, where a difference-in-

difference estimator is associated with causal interpretation, because there are no treatment and control groups, a difference-in-decompositions considers changes in structural and compositional results associated with an event, and estimated difference-in-decomposition coefficients are not interpreted as causal.

## 5.2. Within-Group Decompositions

Independent and Integrated returns are decomposed into within-group difference-in-decomposition estimators. Returns are first differenced within Independent and Integrated sectors, and the across post and pre-fracking periods. Equation (6) is the within-group Independent-Integrated post and pre-fracking return difference-in-decompositions observed at post fracking returns to characteristics.

$$\begin{aligned} (R_i^{post} - R_i^{pre}) - (R_m^{post} - R_m^{pre}) = & ((\alpha_i^{post} - \alpha_i^{pre}) - (\alpha_m^{post} - \alpha_m^{pre})) + ((\beta_i^{post} - \beta_i^{pre}) X_i^{pre} - (\beta_m^{post} - \beta_m^{pre}) X_m^{pre}) \\ & + ((X_i^{post} - X_i^{pre}) \beta_i^{post} - (X_m^{post} - X_m^{pre}) \beta_m^{post}) \end{aligned} \quad (\text{Equation 6})$$

Equation (7) is the within-group Independent-Integrated post and pre-fracking estimator observed at post fracking averages and pre-fracking returns to characteristics.

$$\begin{aligned} (R_i^{post} - R_i^{pre}) - (R_m^{post} - R_m^{pre}) = & ((\alpha_i^{post} - \alpha_i^{pre}) - (\alpha_m^{post} - \alpha_m^{pre})) + ((\beta_i^{post} - \beta_i^{pre}) X_i^{post} - (\beta_m^{post} - \beta_m^{pre}) X_m^{post}) \\ & + ((X_i^{post} - X_i^{pre}) \beta_i^{pre} - (X_m^{post} - X_m^{pre}) \beta_m^{post}) \end{aligned} \quad (\text{Equation 7})$$

## 5.3. Across-Group Decompositions

Independent and Integrated returns are decomposed with across-group difference-in-decomposition estimators. Returns are first differenced across Independent and Integrated sectors and then across post and pre periods. Equation (8) is the across-group difference-in-decompositions observed at Integrated averages at Independent returns to characteristics.

$$(R_m^{post} - R_i^{post}) - (R_m^{pre} - R_i^{pre}) = ((\alpha_m^{post} - \alpha_i^{post}) - (\alpha_m^{pre} - \alpha_i^{pre})) + ((\beta_m^{post} - \beta_i^{post}) X_m^{post} - (\beta_m^{pre} - \beta_i^{pre}) X_m^{pre})$$

$$+\left((X_m^{post} - X_i^{post})\beta_i^{post} - (X_m^{pre} - X_i^{pre})\beta_i^{pre}\right) \quad (\text{Equation 8})$$

Equation (9) is the across-group difference-in-decompositions observed at Independent averages at Integrated returns to characteristics.

$$\begin{aligned} (R_m^{post} - R_i^{post}) - (R_m^{pre} - R_i^{pre}) = & \left((\alpha_m^{post} - \alpha_i^{post}) - (\alpha_m^{pre} - \alpha_i^{pre})\right) + \left((\beta_m^{post} - \beta_i^{post})X_i^{post} - (\beta_m^{pre} - \beta_i^{pre})X_i^{pre}\right) \\ & + \left((X_m^{post} - X_i^{post})\beta_m^{post} - (X_m^{pre} - X_i^{pre})\beta_m^{pre}\right) \end{aligned} \quad (\text{Equation 9})$$

Difference-in-decompositions partition relative risk sources created with the fracking revolution.

## VI. Results

### 6.1 Independent and Integrated Within-Group Difference-in-Decomposition

The Independent-Integrated within-group difference-in-decompositions are presented in Tables 10 through 13. Panel A is the within-group Independent post-pre fracking decomposition. Panel B is the within-group Integrated post-pre fracking decomposition. Panel C is the within-group difference-in-decompositions and is the difference between Panels A and B. Because each element in Panels A and B are the post and pre-fracking Independent-Integrated percent differences, Panel C elements are the percent differences in the post-pre within-group decompositions. To highlight the fracking revolution's industry realignment, only S&P 500, brent crude, natural and conventional gas, diesel, and aviation fuel are considered. Levels are aggregate decompositions. Proportions by characteristics are specific decompositions (An and Glynn, 2019, p. 1006)

**Table 10, Exploration & Production Within-Group Difference-in-Decompositions**

<i>Panel A</i>				
<b>Independent</b>	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Post}$	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Post}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Pre}$
Levels				
Sum	-.0009	-.0003	-.0014	.0002
Total		-.0012		-.0012
Proportions				
Intercept	.5785		.5785	
SNP	.0080	-.2484	.0217	-.2620
SMB	.0073	.0925	.0142	.0710
HML	.0034	.0483	.0093	.0424
RMW	.3570	-.1914	.1040	.0615
CMA	-.1054	.1249	.2366	-.2171
MOM	-.0957	.1816	.1563	-.0704
Crude	.0243	.0390	-.0038	.0671
Natural Gas	.0003	-.0085	.0010	-.0091
Conventional Gas	.0187	.0193	.0047	.0333
Diesel	-.0239	.1520	.0136	.1146
Aviation	.0030	.0298	-.0013	.0340
Fuel				
Sum	.7609	.2391	1.135	-.135
Total		1		1
<i>Panel B</i>				
<b>Integrated</b>	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Post}$	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Pre}$
Levels				
Sum	-.0007	.0001	-.0011	.0005
Total		-.0007		-.0007
Proportions				
Intercept	.8355		.8355	
SNP	.0262	-.06322	.1600	-.7660
SMB	.0341	-.0051	.0812	-.1204
HML	.0467	.0868	.1320	.0016
RMW	.3946	-.1789	.1144	.1013
CMA	-.1006	.2509	.2187	-.0684
MOM	-.0729	.1698	.1800	-.0831
Crude	.0059	.0443	.0007	.0495
Natural Gas	-.0007	7.22 <sup>-5</sup>	-.0024	.0018
Conventional Gas	.0062	.0225	.0025	.0262
Diesel	-.0344	.1425	.0143	.0938
Aviation	.0059	.0209	-.0019	.0287
Fuel				
Sum	1.078	-.078	1.735	-.7349
Total				
<i>Panel C</i>				
<b>ENP DID</b>	Equation 6	Equation 7	Equation 6	Equation 7
Levels				

Sum	-.0002	-.0004	-.0003	-.0003
Total		-.0006		-.0006
Proportions				
Intercept	-.2570		-.2570	
SNP	-.0182	.3838	-.1384	.5040
SMB	.0680	.0976	-.0670	.1914
HML	-.0434	-.0386	-.1227	.0408
RMW	-.0376	-.0126	-.0104	-.0400
CMA	-.0047	-.1260	.0179	-.1487
MOM	-.0228	.0118	-.0237	.0127
Crude	.0184	-.0052	-.0045	.0176
Natural Gas	.0011	-.0086	.0034	-.0109
Conventional Gas	.0125	-.0033	.0021	.0070
Diesel	.0105	.0095	-.0008	.0208
Aviation Fuel	-.0030	.0088	.0006	.0053
Sum	-.3174	.3174	-.6002	.6002

**Source:** See Table 5 and 7.

Table 11, Equipment &amp; Services Within-Group Difference-in-Decompositions

<i>Panel A</i>				
<b>Independent</b>	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Post}$	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Post}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Pre}$
Levels				
Sum	-.0012	.0003	-.0007	-.0002
Total		-.0009		-.0009
Proportions				
Intercept	.6117		.6117	
SNP	.0518	.2877	.0233	.3162
SMB	.0084	-.1258	-.0039	-.1135
HML	.1025	-.0957	.0359	-.0292
RMW	.0733	.2029	.2667	.0096
CMA	.2707	-.1641	-.1278	.2344
MOM	.1830	-.2251	-.0776	.0355
Crude	-.0003	-.0375	-.0131	-.0247
Natural Gas	.0067	.0019	.0029	.0056
Conventional Gas	.0093	-.0131	.0292	-.0330
Diesel	-.0063	-.0943	.0100	-.1105
Aviation	-.0031	-.0446	.0063	-.0540
Fuel				
Sum	1.308	-.3077	.7635	.2365
Total		1		1
<i>Panel B</i>				
<b>Integrated</b>	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Post}$	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Pre}$
Levels				
Sum	-.0007	-5.127 <sup>-5</sup>	-.0011	.0005
Total		-.0007		-.0007
Proportions				
Intercept	.8355		.8355	
SNP	.0262	-.6322	.1600	-.0766
SMB	-.0341	-.0051	.0812	-.1204
HML	.0467	.0868	.1320	.0016
RMW	.3946	-.1789	.1144	.1013
CMA	-.1006	.2509	.2187	-.0684
MOM	-.0729	.1698	.1800	-.0831
Crude	.0059	.0443	.0007	.0495
Natural Gas	-.0008	.0001	-.0024	.0018
Conventional Gas	.0062	.0225	.0025	.0262
Diesel	-.0344	.1425	.0143	.0938
Aviation	.0059	.0209	-.0019	.0287
Fuel				
Sum	1.078	-.0782	1.735	-.7349
Total		1		1
<i>Panel C</i>				
<b>ENS DID</b>				
Levels	Equation 6	Equation 7	Equation 6	Equation 7

Sum	-.0005	.0002	.0004	-.0007
Total		-.0003		-.0003
Proportions				
Intercept	-.2238		-.2238	
SNP	.0256	.9198	-.1367	1.082
SMB	.0425	-.1207	-.0850	.0069
HML	.0557	-.1826	-.0961	-.0308
RMW	-.3213	.3817	.1523	-.0918
CMA	.3713	-.4150	-.3465	.3028
MOM	.2559	-.3948	-.2576	.1187
Crude	-.0062	-.0818	-.0138	-.0742
Natural Gas	.0075	.0018	.0054	.0039
Conventional Gas	.0031	-.0356	.0267	-.0592
Diesel	.0281	-.2368	-.0044	-.2043
Aviation Fuel	-.0090	-.0655	.0082	-.0827
Sum	.2294	-.2294	-.9715	.9715

**Source:** See Table 6 and 7.



**Table 12, Transportation & Pipeline Within-Group Difference-in-Decompositions**

<i>Panel A</i>				
<b>Independent</b>	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Post}$	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Post}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Pre}$
Levels				
Sum	-.0010	.0002	-.0011	.0003
Total		-.0008		-.0008
Proportions				
Intercept	1.030		1.030	
SNP	-.0236	-.5751	-.2094	-.3892
SMB	.0004	.1011	.0105	.0910
HML	-.0977	.0004	-.1731	.0759
RMW	.3681	-.3361	.0787	-.0467
CMA	-.0450	.2182	.3506	-.1773
MOM	.0840	.0789	.2132	-.0503
Crude	-.0261	.0335	-.0007	.0080
Natural Gas	-4.194 <sup>-4</sup>	-.0036	.0042	-.0079
Conventional Gas	.0010	.0236	.0002	.0243
Diesel	-.0952	.2533	.0545	.1036
Aviation	-.0176	.0272	.0081	.0016
Fuel				
Sum	1.179	-.178	1.367	-.367
Total				
<i>Panel B</i>				
<b>Integrated</b>	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Post}$	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Pre}$
Levels				
Sum	-.0007	5.130 <sup>-5</sup>	-.0011	.0005
Total		-.0007		-.0007
Proportions				
Intercept	.8355		.8355	
SNP	.0262	-.6322	.1600	-.7660
SMB	-.0341	.0051	.0812	-.1204
HML	.0467	.0868	.1320	.0016
RMW	.3946	-.1789	.1144	.1013
CMA	-.1006	.2509	.2187	-.0684
MOM	-.0729	.1700	.1800	-.0831
Crude	.0059	.0443	.0007	.0495
Natural Gas	-.0008	7.220 <sup>-5</sup>	-.0024	.0018
Conventional Gas	.0062	.0225	.0025	.0262
Diesel	-.0344	.1425	.0143	.0938
Aviation	.0059	.0209	-.0019	.0287
Fuel				
Sum	1.078	-.0783	1.735	-.7349
Total				
<i>Panel C</i>				
<b>TNP DID</b>				
Levels	Equation 6	Equation 7	Equation 6	Equation 7

Sum	-.0003	9.630 <sup>-5</sup>	-.0011	.0005
Total		-.0002		-.0002
Proportions				
Intercept	.1948		.1948	
SNP	-.0498	.0571	-.3694	.3767
SMB	.0345	.1062	-.0707	.2113
HML	-.1444	-.0864	-.3051	.0743
RMW	-.0265	-.1572	-.0357	-.1480
CMA	.0557	-.0327	.1316	-.1089
MOM	.1570	-.0909	.0332	.0328
Crude	-.0321	-.0108	-.0014	-.0415
Natural Gas	.0007	-.0037	.0067	-.0097
Conventional Gas	-.0052	.0011	-.0023	-.0019
Diesel	-.0608	.1108	.0402	.0098
Aviation	-.0235	.0063	.0099	-.0271
Fuel				
Sum	.1003	-.1003	-.3679	.3679

**Source: Tables 8 and 7.**

**Table 13, Refining & Mining Within-Group Difference-in-Decompositions**

<i>Panel A</i>				
<b>Independent</b>	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Post}$	$(\beta_i^{Post} - \beta_i^{Pre}) X_i^{Post}$	$(\bar{X}_i^{Post} - \bar{X}_i^{Pre}) \beta_i^{Pre}$
Levels				
Sum	-.0007	-.0003	-.0011	.0001
Total		-.0010		-.0010
Proportions				
Intercept	.7691		.7691	
SNP	-.0849	.1865	-.0582	.1598
SMB	.0298	.0371	.0569	.0100
HML	.0314	.0586	.0663	.0237
RMW	-.1876	-.1264	-.0058	-.3082
CMA	-.0416	.0130	.0835	-.1121
MOM	.1231	.0165	.1768	-.0371
Crude	.0102	.0161	.0002	.0261
Natural Gas	-.0041	.0063	.0030	-.0007
Conventional Gas	.0764	.0267	.0204	.0827
Diesel	-.0976	.0885	.0515	-.0606
Aviation	.0509	.0019	-.0229	.0756
Fuel				
Sum	.6752	.3248	1.141	-.1408
Total		1		1
<i>Panel B</i>				
<b>Integrated</b>	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Post}$	$(\beta_m^{Post} - \beta_m^{Pre}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_m^{Pre}) \beta_m^{Pre}$
Levels				
Sum	-.0007	5.130 <sup>-5</sup>	-.0011	.0005
Total		-.0007		-.0007
Proportions				
Intercept	.8355		.8355	
SNP	.0262	-.6322	.1600	-.7660
SMB	-.0341	.0051	.0812	-.1204
HML	.0467	.0868	.1320	.0016
RMW	.3946	-.1789	.1144	.1013
CMA	-.1006	.2509	.2187	-.0684
MOM	-.0729	.1700	.1800	-.0831
Crude	.0059	.0443	.0007	.0495
Natural Gas	-.0008	7.220 <sup>-5</sup>	-.0024	.0018
Conventional Gas	.0062	.0225	.0025	.0262
Diesel	-.0344	.1425	.0143	.0938
Aviation	.0059	.0209	-.0019	.0287
Fuel				
Sum	1.078	-.0783	1.735	-.7349
Total	-.0007	5.130 <sup>-5</sup>	-.0011	.0005
<i>Panel C</i>				
<b>RNM DID</b>				
Levels	Equation 6	Equation 7	Equation 6	Equation 7

Sum	.0001	-.0004	2.182 <sup>-5</sup>	-.0003
Total		-.0003		-.0001
Proportions				
Intercept	-.0664		-.0664	
SNP	-.1111	.8187	-.2182	.9257
SMB	.0638	.0422	-.0243	.1304
HML	-.0153	-.0283	-.0657	.0221
RMW	-.5822	.0525	-.1201	-.4096
CMA	.0591	-.2379	-.1352	-.0436
MOM	.1961	-.0153	-.0032	.0460
Crude	.0043	-.0281	-.0005	-.0234
Natural Gas	-.0033	.0063	.0054	-.0025
Conventional Gas	.0702	.0042	.0179	.0565
Diesel	-.0632	-.0540	.0371	-.1544
Aviation Fuel	.0450	-.0191	-.0210	.0469
Sum	-.4032	.4031	-.5942	.5942

**Source:** See Tables 9 and 7.

### **6.1.1 Within-group Independent Decompositions**

Tables' 10 through 13, Panel A are Independent post-pre fracking decompositions and is the measure for before-after Independent variation with the fracking revolution. Panel A characteristic elements are positive if within-group Independent returns increase with the fracking revolution, and negative if Independent returns decreased with the fracking revolution. From specific decompositions, exploration & production post fracking returns increased across equity and commodity returns, save diesel, indicating that fracking technologies increased Independent returns for infrastructure closest to extraction (Panel A; Gold, 2013, p. 129). Equipment & service equity and distillate returns were higher after fracking from equity, natural gas, and conventional gas but were lower from crude, diesel, and aviation. Transportation & pipeline post fracking conventional gas is the only return that increased with fracking; transportation & pipeline returns were higher before the fracking revolution for equity and commodity returns, except conventional gas. Refining & marketing crude, conventional gas, and aviation fuel returns were higher after fracking and lower for equity, natural gas, and diesel, indicating that midstream and downstream Independent returns decreased in the post-fracking period and had measurable spillover effects associated with the fracking revolution (Panel A). Independent diesel post fracking returns decreased across the oil and gas industry and were higher after fracking for conventional gas (Panel A), and multiple fracking technologies increased returns closest to oil and gas extraction.

### **6.1.2 Within-group Integrated Decompositions**

Panel B characteristic elements are positive if within-group vertically Integrated returns increased within the fracking revolution, and negative if Integrated returns decreased with the fracking revolution. Integrated post fracking returns increased with equity, commodity, conventional gas, and aviation fuel and decreased with natural gas and diesel, indicating the fracking revolution also increased Integrated returns closest to oil and gas extraction. From the start, the fracking revolution changed relationships between Independent and Integrated equity and commodity market returns and risk, and across the industry, within-group returns to equity market relationships were greater than commodity markets.

### **6.1.3 Within-Group Difference in Decompositions**

Within-group differences-in-decomposition signs indicate fracking revolution risk and return variation (Panel C). If characteristic elements are positive, Independent gaps increased with the fracking revolution relative to vertically Integrated gaps and negative if vertically Integrated gaps increased with fracking compared to Independent producers. Exploration & production within-group differences-in-decompositions indicate that post-fracking return gaps increased compared to Integrated from crude, natural gas, conventional gas, and diesel, and decreased from equity and aviation fuel gaps, indicating that fracking technologies increased Independent relative to Integrated within-group returns closest to oil and gas extraction. Only the Integrated to exploration & production Independent returns gap increased with equity and aviation fuel. Subsequent 2020's oil and gas mergers and acquisitions indicate that large vertically integrated firms recognized their smaller exploration & production advantages and engaged in a post-fracking mergers to acquire smaller producers closer to oil and gas extraction (Gold, 2013, p. 134). Equipment & service equity, natural gas, conventional gas, and diesel return gaps increased with fracking and Integrated return gaps increased in crude commodity and aviation fuel gaps. The fracking revolution shifted several well completions to equipment & service firms, that reflect upstream technologies, creating market value.

Transportation & pipeline Independent to Integrated return gaps only increased in natural gas, whereas Integrated returns gaps increased from equity, commodity, conventional gas, diesel, and aviation fuel with the fracking revolution. Refining & marketing Independent to Integrated return gaps increased for crude, conventional gas, and aviation fuel, while Integrated to refining & marketing gaps increased in equity, natural gas, and diesel. With more stable access to oil and gas, downstream transportation & pipeline and refining & marketing equity returns decreased with fracking, indicating that downstream Independent firm values decreased with fracking revolution New Growth factors.

## **6.2 Independent and Integrated Across-Group Difference-in-Decomposition**

Tables 14 through 17, Panel A are the across-group Integrated-Independent post-fracking returns decompositions. Panel A elements are positive if vertically Integrated returns were higher than Independents after fracking and negative if Independent returns were higher than vertically Integrated after fracking. Panel B is the across-group Independent-Integrated pre-fracking decompositions, and elements are positive if vertically Integrated returns were higher than Independents before the fracking revolution and negative if Independent returns were higher than Integrated before fracking. Panel C is the difference-in-decompositions between Panels A and B and are positive if post-fracking Integrated to Independent gaps increased with the fracking revolution and negative if post fracking Independent gaps increased relative to vertically Integrated.

**Table 14, Exploration & Production Across-Group Decomposition**

<i>Panel A</i>				
<b>ENP</b>	$(\beta_m^{Post} - \beta_i^{Post}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_i^{Post}$	$(\beta_m^{Post} - \beta_i^{Post}) X_i^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_m^{Post}$
<b>Post</b>				
Levels				
Sum	-1.402 <sup>-5</sup>	.0001	-2.198 <sup>-5</sup>	.0001
Total		9.800 <sup>-5</sup>		9.800 <sup>-5</sup>
Proportions				
Intercept	-1.117		-1.447	
SNP	-1.333	1.376	-1.046	1.089
SMB	.8384	-.0382	.7990	.0011
HML	.0362	.0287	.0373	.0276
RMW	.4507	.0603	.4797	.0314
CMA	-.1065	.0547	-.1121	.0603
MOM	1.372	-.7450	.8997	-.2779
Crude	.0050	.1005	-.0098	.1153
Natural Gas	-.1796	.0138	-.1658	-5.401 <sup>-5</sup>
Conventional Gas	-.0238	.0448	-.0154	.0364
Diesel	.2017	.2161	.2922	.1256
Aviation	.0437	.0359	.0641	.0155
Fuel				
Sum	-.1431	1.143	-.2243	1.224
Total				
<i>Panel B</i>				
<b>Pre</b>	$(\beta_m^{Pre} - \beta_i^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_i^{Pre}$	$(\beta_m^{Pre} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_m^{Pre}$
Levels				
Sum	-.0004	-.0001	-.0004	-.0001
Total		-.0005		-.0005
Proportions				
Intercept	.6400		.6400	
SNP	.0201	.1710	.0357	.1554
SMB	.0999	.0086	.1163	.0078
HML	-.0569	-.0035	-.0602	-6.995 <sup>-5</sup>
RMW	.0174	.0122	.0184	.0112
CMA	-.1377	-.0031	-.1402	.0005
MOM	-.0364	.0006	-.0361	.0003
Crude	.0255	.0470	.0374	.0351
Natural Gas	.0129	.0004	.0134	-3.481 <sup>-5</sup>
Conventional Gas	.0486	.0051	.0509	.0028
Diesel	.0857	.0113	.0913	.0057
Aviation	.0270	.0042	.0290	.0022
Fuel				
Sum	.7462	.2538	.7958	.2042
Total		1		1
<i>Panel C</i>				



<b>ENP DID</b>				
Levels	Equation 8	Equation 9	Equation 8	Equation 9
Sum	.0004	.0002	.0004	.0002
Total		.0006		.0006
Proportions				
Intercept	-2.087		-2.087	
SNP	-1.353	1.205	-.1082	.9336
SMB	.7385	-.0468	.6827	.0089
HML	.0930	.0322	.0975	.0277
RMW	.4333	.0481	.4613	.0202
CMA	.0312	.0577	.0281	.0608
MOM	1.408	-.7504	.9358	-.2781
Crude	-.0204	.0534	-.0472	.0802
Natural Gas	-.1925	.0134	.1791	-1.920 <sup>-5</sup>
Conventional Gas	-.0723	.0397	-.0663	.0336
Diesel	.1160	.2049	.2010	.1199
Aviation	.0167	.0318	.0351	.0134
Fuel				
Sum	-.8893	.8893	-1.020	1.020

See Table 5 and 7.

Table 15, Equipment &amp; Service Across-Group Difference-in-Decompositions

<i>Panel A</i>					
<b>ENS</b>		$(\beta_m^{Post} - \beta_i^{Post}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_i^{Post}$	$(\beta_m^{Post} - \beta_i^{Post}) X_i^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_m^{Post}$
<b>Post</b>					
Levels					
Sum		.0002	9.400 <sup>-5</sup>	.0001	.001
Total			.0002		.0002
Proportions					
Intercept		-.0132		-.0132	
SNP		-.4821	.5449	-.3786	.4414
SMB		.3450	-.0056	.3393	.0002
HML		.1949	.0020	.1956	.0013
RMW		.1058	-.0110	.1021	-.0069
CMA		-.0462	.0045	-.0467	.0050
MOM		.5038	-.2290	.3652	-.0904
Crude		-.0021	.0147	-.0004	.0130
Natural Gas		-.0137	.0008	-.0129	-1.665 <sup>-5</sup>
Conventional Gas		.0109	.0080	.0081	.0108
Diesel		-.0169	.0421	-.0243	.0495
Aviation Fuel		.0234	.0188	.0351	.0067
Sum		.6097	.3903	.5694	.4306
Total			1		1
<i>Panel B</i>					
<b>Pre</b>		$(\beta_m^{Pre} - \beta_i^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_i^{Pre}$	$(\beta_m^{Pre} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_m^{Pre}$
Levels					
Sum		3.334 <sup>-5</sup>	-.0001	2.118 <sup>-5</sup>	-.0001
Total			-8.934 <sup>-5</sup>		-8.934 <sup>-5</sup>
Proportions					
Intercept		.2072		.2072	
SNP		.1321	1.419	.2842	1.267
SMB		.6033	.0240	.6456	-.0183
HML		-.1565	.0013	-.1553	4.948 <sup>-5</sup>
RMW		-.1.179	-.0024	-1.200	.0185
CMA		-.5881	-.0280	-.6101	-.0059
MOM		.0321	.0346	.0244	.0424
Crude		-.1378	-.0133	-.1311	-.0201
Natural Gas		.0398	.0112	.0528	-.0019
Conventional Gas		.1976	-.0242	.1885	-.0150
Diesel		.2509	-.0384	.2378	-.0253
Aviation Fuel		.2256	-.0110	.2192	-.0046
Sum		-.3731	1.373	-.2371	1.237
Total			1		1
<i>Panel C</i>					
<b>ENS DID</b>					

Levels	Equation 8	Equation 9	Equation 8	Equation 9
Sum	.0001	.0002	.0001	.0002
Total		.0003		.0003
Proportions				
Intercept	.2204		.2204	
SNP	-.6142	-.8755	-.6628	-.8258
SMB	-.2583	-.0296	-.3063	.0185
HML	.3514	.0008	.3509	.0013
RMW	1.285	-.0081	1.302	-.0254
CMA	.5418	.0325	.5634	.0106
MOM	.4717	-.2636	.3408	-.1328
Crude	.1357	.0280	.1307	.0331
Natural Gas	-.0534	-.0104	.0357	.0019
Conventional Gas	-.1867	.0322	-.1803	.0269
Diesel	-.2678	.0805	-.2620	.0748
Aviation Fuel	-.2022	.0294	-.1841	.0113
Sum	.9829	-.9829	.8065	-.8065

**Source: Table 6 and 7.**

Table 16, Transportation &amp; Services Across-Group Difference-in-Decompositions

<i>Panel A</i>				
<b>TNP</b>	$(\beta_m^{Post} - \beta_i^{Post}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_i^{Post}$	$(\beta_m^{Post} - \beta_i^{Post}) X_i^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_m^{Post}$
<b>Post</b>				
Levels				
Sum	-.0005	9.705 <sup>-5</sup>	-.0005	9.293 <sup>-5</sup>
Total		-.0004		-.0004
Proportions				
Intercept	1.300		1.30	
SNP	.4655	-.3652	.3650	-.2647
SMB	-.2497	.0289	-.2200	-.0007
HML	.216	4.320 <sup>-5</sup>	.2113	.0048
RMW	-.0738	.0051	-.0718	.0032
CMA	-.1127	-.0046	-.1140	-.0033
MOM	-.2395	.1690	-.1466	.0760
Crude	-.0009	-.0068	-.0002	-.0074
Natural Gas	.0081	-.0006	.0075	1.279 <sup>-5</sup>
Conventional Gas	.0013	-.0100	.0008	-.0096
Diesel	-.0695	-.0514	-.0954	-.0254
Aviation	-.0046	-.0048	-.0063	-.0031
Fuel				
Sum	1.240	-.240	1.230	-.230
Total		1		1
<i>Panel B</i>				
<b>Pre</b>	$(\beta_m^{Pre} - \beta_i^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_i^{Pre}$	$(\beta_m^{Pre} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_m^{Pre}$
Levels				
Sum	-.0006	8.879 <sup>-6</sup>	-.0005	-4.238 <sup>-5</sup>
Total		-.0006		-.0006
Proportions				
Intercept	1.441		1.441	
SNP	-.0392	-.0607	-.0211	-.0788
SMB	.1051	-.0697	-.0083	.0437
HML	-.0895	-.0505	-.1395	-.0006
RMW	-.2270	-.0207	-.2996	.0519
CMA	-.0781	.0737	-.0220	.0176
MOM	-.0517	.1259	.0308	.0435
Crude	-.0513	-.0006	-.0488	-.0031
Natural Gas	.0047	-.0039	-.0001	.0009
Conventional Gas	-.0035	-9.675 <sup>-5</sup>	-.0035	-.0001
Diesel	.0194	-8.139 <sup>-5</sup>	.0194	-6.475 <sup>-5</sup>
Aviation	-.0234	-9.211 <sup>-5</sup>	-.0219	-.0014
Fuel				
Sum	1.007	-.0067	.9638	.0736
Total		1		1
<i>Panel C</i>				

<b>TNP DID</b>				
Levels	Equation 8	Equation 9	Equation 8	Equation 9
Sum	7.854 <sup>-5</sup>	9.317 <sup>-5</sup>	3.640 <sup>-5</sup>	.0001
Total		.0002		.0002
Proportions				
Intercept	-.1413		-.1413	
SNP	.5047	-.3045	.3861	-.1859
SMB	.3548	.0986	-.2118	-.0444
HML	.3056	.0506	.3508	.0054
RMW	.1543	.0258	.2278	-.0488
CMA	-.0345	-.0783	-.0919	-.0209
MOM	-.1878	.0430	-.1773	.0325
Crude	.0505	-.0062	.0486	-.0043
Natural Gas	.0035	.0033	.0076	-.0009
Conventional Gas	.0047	-.0100	.0043	-.0095
Diesel	-.0888	-.0513	-.1148	-.0254
Aviation	.0187	-.0047	.0156	-.0017
Fuel				
Sum	.2336	-.2336	.3037	-.3037

**Source:** See Tables 8 and 7.

Table 17, Refining &amp; Marketing Across-Group Difference-in-Decompositions

<i>Panel A</i>					
<b>RNM</b>		$(\beta_m^{Post} - \beta_i^{Post}) X_m^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_i^{Post}$	$(\beta_m^{Post} - \beta_i^{Post}) X_i^{Post}$	$(\bar{X}_m^{Post} - \bar{X}_i^{Post}) \beta_m^{Post}$
<b>Post</b>					
Levels					
Sum		.0008	.0001	.0007	.0002
Total			.0009		.0009
Proportions					
Intercept		.7136		.7136	
SNP		.1032	.1791	.0696	.2127
SMB		-.0683	.0007	-.0879	.0188
HML		-.0209	.0018	-.0213	.0022
RMW		.0235	-.0454	.0034	-.0254
CMA		.1151	-.0075	.1082	-.0006
MOM		-2.826 <sup>-6</sup>	.0289	-1.897 <sup>-4</sup>	-.0289
Crude		-.0020	.0035	-.0004	.0018
Natural Gas		-.0043	-2.541 <sup>-4</sup>	-.0029	-.0015
Conventional Gas		.0062	.0045	.0038	.0070
Diesel		.0081	.0146	.0120	.0108
Aviation Fuel		.0032	.0018	.0048	.0002
Sum		.8773	.1227	.8029	.1971
Total			1		1
<i>Panel B</i>					
<b>Pre</b>		$(\beta_m^{Pre} - \beta_i^{Pre}) X_m^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_i^{Pre}$	$(\beta_m^{Pre} - \beta_i^{Pre}) X_i^{Pre}$	$(\bar{X}_m^{Pre} - \bar{X}_i^{Pre}) \beta_m^{Pre}$
Levels					
Sum		-.0005	.0004	-.0003	-.0006
Total			-.0009		-.0009
Proportions					
Intercept		.9060		.9060	
SNP		-.0169	.4426	-.1015	.5272
SMB		-.0094	.0019	-.0515	.0650
HML		.0007	-.0006	-.0215	-.0002
RMW		.0972	-.0102	-.4709	.0382
CMA		-.0820	-.0060	-.0236	-.0003
MOM		.0370	.0023	.0698	.0362
Crude		.0321	-.0186	.0088	-.0026
Natural Gas		-.0158	-.0060	-.0020	.0022
Conventional Gas		-.3408	-.0919	.0895	-.0025
Diesel		-.0232	-.0007	-.0957	.0078
Aviation Fuel		-.0605	.1664	.0386	.0007
Sum		.5245	.4755	.3282	.6718
Total			1		1
<i>Panel C</i>					
<b>RNM DID</b>					

Levels	Equation 8	Equation 9	Equation 8	Equation 9
Sum	.0013	.0006	.0010	.0008
Total		.0018		.0018
Proportions				
Intercept	-.1924		-.1924	
SNP	.1201	.2636	.1711	-.3146
SMB	-.0589	.0012	-.0363	-.0462
HML	-.0216	.0024	.0003	.0024
RMW	-.0738	-.0352	.4744	-.0636
CMA	.1970	-.0015	.1318	-.0003
MOM	-.0370	-.0312	-.0698	-.0651
Crude	-.0341	.0221	.0085	.0044
Natural Gas	.0115	.0059	-.0008	-.0036
Conventional Gas	.3470	.0964	-.0857	.0094
Diesel	.0313	.0153	.1077	.0029
Aviation	.0637	-.1646	-.0338	-.0005
Fuel				
Sum	.3528	-.3528	.4747	-.4747

**Source:** See Tables 9 and 7.

### **6.2.1 Across Group post-Fracking Returns**

Tables 14 through 17, Panel A are the Integrated-Independent post fracking returns differences. Post fracking exploration & production were higher than Integrated in commodity, diesel, and aviation fuels, and lower in equity, natural gas, and conventional gas. Post fracking Integrated to equipment & service Independent return gaps were higher in conventional gas and aviation fuels and lower in equity, crude, natural gas, and diesel. Post fracking Integrated return gaps were higher than transportation & pipeline in equity, natural gas, and conventional gas and lower in crude, diesel, and aviation. Downstream refining & marketing post fracking Integrated to Independent return gaps were higher in equity, conventional gas, diesel, and aviation fuel, and lower in crude and natural gas.

### **6.2.2 Across Group Pre-Fracking Decompositions**

From specific decompositions, pre-fracking Integrated to exploration & production Independent return gaps were higher for equity, commodity, natural gas, conventional gas, and aviation fuels (Panel B). Similarly, pre-fracking equipment & service equity, natural gas, conventional gas, and aviation fuel, and only pre fracking crude favored Independent equipment & service. Pre-fracking Integrated to Independent transportation & pipeline were higher in natural gas and diesel and lower with equity, crude, conventional gas, and aviation fuels. Similarly, pre-fracking Integrated to refining & marketing Independent were higher for crude and diesel but were lower for equity, natural gas, conventional gas, and aviation fuel.

### **6.2.3 Across Group Difference-in-Decomposition**

Across-group difference-in-decomposition elements indicate fracking increased Integrated to exploration & production returns for diesel and aviation fuel, and decreased the exploration & production gap in equity, commodity, natural gas, and conventional return gaps (Panel C). Exploration & production



across-group Independent equity return gaps increased the most for any returns gap, either within or across decompositions, indicating that the greatest industry fracking realignment was in equity markets as participants increased upstream exploration & production returns closer to oil and gas extraction. The equipment & service Integrated to Independent gap only increased for crude returns, but were lower across remaining equity and distillate returns. The fracking revolution shifted more well completions to equipment & service, and Integrated to Independent equipment & service also decreased with fracking. Alternatively, the fracking revolution increased the vertically Integrated mid and downstream transportation & pipeline and refining & marketing return gaps in equity, crude, and distillate markets.

## **VII. Conclusion**

Innovations in the oil and gas industry increased industry productivity, and improvements were not shared uniformly across the oil and gas industry. The fracking revolution changed within-group technology that favored Independent firms who outperformed larger Integrated producers. For example, as the industry realigned, fracking technologies increased Independent returns closest to oil and gas extraction and decreased mid and downstream returns. Equipment & services Independent to Integrated return differences were also higher with the fracking revolution, and fracking technologies increased upstream Independent relative to Integrated returns gaps closest to oil and gas extraction and decreased downstream Independent to Integrated returns. Independent-Integrated within-group commodity differences are greater after the revolution with exploration & production and equipment & service, while pre-fracking risk and returns transportation & pipeline and refining & marketing were higher prior to the revolution. The post-revolution merge and acquisition wave reflects industry realignment, where large vertically Integrated majors recognized these upstream producer's value from upstream technologies with access to mineral rights and acquired or merged with exploration & production and equipment & service firms.

Exploration & production across-group Independent equity return gaps increased the most for any returns gap, either within or across decompositions, indicating that the greatest fracking industry realignment was in equity markets as participants increased upstream exploration & production returns closer to oil and gas extraction. While not this study's primary objective, increasing characteristic returns to include distillates indicate that Integrated and Independents were affected differently across equities and commodity risk. The oil and gas fracking revolution illustrates that innovation occurs across industry networks, and New Economic Growth Theory integrates knowledge, human capital, and positive geographic externalities to analyze growth that results from endogenous relationships.

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