TGIF? The Weekend Effect in Energy Commodities

Seth A. Hoelscher, Cedric Mbanga, and Walt A. Nelson

Abstract

While there exists today ample evidence of the weekend effect in the equity and currency markets, similar evidence in the commodities market remains sparse. In this paper, we investigate the presence of the weekend effect in crude oil and natural gas markets. The sample uses daily spot returns in crude oil (WTI and Brent) and natural gas markets from the U.S. Energy Information Administration for periods beginning as early as data is available (1986, 1987, and 1997 respectively) through May 2017. We estimate robust OLS and median regression models across the entire sample period and three approximately equal subperiods for each of the commodities. We find evidence of the weekend effect for WTI and Brent commodities while documenting a "reverse" weekend effect in natural gas returns.

I. Introduction and Literature Review

Observed patterns in asset prices which contradict the efficient market hypothesis are commonly referred to as market anomalies. An important example is the "calendar anomaly," which is understood to be systematic asset price behaviors which are inconsistent with the notion of market efficiency and routinely observed at different times of the year. Examples of calendar effects documented in the asset pricing literature include the weekend effect (e.g., Alt, Fortin, and Weinberger, 2011; Blau, Van Ness, and Van Ness, 2009; Christophe, Ferri, and Angel, 2009), the intramonth and turn-of-the-month effects (e.g., Compton, Kunkel, and Kuhlemeyer, 2013; Jalonen, Vähämaa, and Äijö, 2010; Kunkel, Compton, and Beyer, 2003; Wiley and Zumpano, 2009), the day of the week effect (e.g., Seif, Docherty, and Shamsuddin, 2017), the January effect (e.g., Agnani and Aray, 2011; Easterday, Sen, and Stephan, 2009; Sun and Tong, 2010), the Daylight Saving Effect (e.g., Gerlach (2010); Gregory-Allen, Jacobsen, and Marquering, 2010; Kamstra, Kramer, and Levi, 2000), the lucky numbered days (e.g., Haggard, 2015), the Halloween effect (e.g., Andrade, Chhaochharia, and Fuerst, 2013; Haggard, Jones, and Witte, 2015; Jacobsen and Visaltanachoti, 2009), and the holiday effect (e.g., Gama and Vieira, 2013; Yatrakis and Williams, 2010; Yuan and Gupta, 2014). The vast research literature concerning the existence of calendar effects provides support for the continued investigation of such anomalies.

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The research cited above shows that various forms of the calendar anomaly, including the weekend effect, exist in equity and currency markets. Corroborative evidence from commodities markets remains sparse. This is noteworthy given the increased popularity and usage of commodities as an asset class for institutional investors. The U.S. Commodity Futures Trading Commission (CFTC hereafter) (2008) cites in a recent report the increase of commodity-related investments from an estimated $15 billion in 2003 to at least $200 billion in 2008 held by institutional investors. Moreover, the CME Group (2017) recently released a report highlighting the leading products traded on their platform for the first quarter of 2017. Among commodities, the West Texas Intermediate Crude Oil (WTI) was the most actively traded followed by Gas with an average daily volume of 1,118,945 and 429,548 contracts traded, respectively. Collectively, this increase in institutional investment in commodities and the recent volume of energy commodities trading make the absence of academic research on the likely cyclicality of returns in energy commodities perhaps more puzzling.

Among the limited body of academic research on the weekend effect in commodities are studies by Ball, Torous, and Tschoegl (1982) and Ma (1986) who find evidence in support of the weekend effect in the gold market.[1] However, the study of petroleum and natural gas markets is largely absent from the literature. In one exception, Kohli (2014) studies the day-of-the-week and month effects in sweet crude oil using a sample from 1983 to 2012 and finds marginal evidence of positive Friday returns for sweet crude. Moreover, evidence initially reported by Connolly (1989) and Chang, Pinegar, and Ravichandran (1993) and later supported by the findings of Kamara (1997) and Chen and Singal (2003) suggest that the weekend effect disappears in equity markets post-1980. Therefore, the important question of whether the weekend effect exists in energy commodities post-1980 remains unanswered.

We study a specific days-of-the-week effect termed the “weekend effect” in the petroleum and natural gas markets. Early evidence of the weekend effect, first reported by Fields (1931), builds on the intuition that risk-averse investors are more likely to close out their positions on Friday afternoon and open those positions back up on Monday morning. Consistent with the proposition of Fields (1931), Cross (1973) reports evidence that Friday returns tend to be higher than Monday returns for the S&P Composite. French (1980) documents a similar behavior for U.S equity returns: equity returns tend to be higher than average on the last trading day of the week (Friday) and lower on the first (Monday).

This study seeks to provide an answer to this question for two benchmark crude oil commodities, West Texas Intermediate Crude Oil (WTI) and Brent Sweet Crude Oil (Brent), and for Henry Hub Natural Gas (Gas). Our study builds on five different model estimation techniques, four being robust estimations (3 OLS and 1 median) to account for outliers within the

[1] For a recent study investigating calendar effects in metal commodity markets please see Borowski and Lukasik (2015).

data. All models are estimated using a parsimonious regression equation to investigate the existence of a potential weekend effect in petroleum and natural gas. In general, we find that a weekend effect for WTI and Brent exists over our entire sample period using robust OLS techniques. That is, the mean Monday returns on both commodities are negative and significant whereas mean Friday returns tend to be flat, statistically indifferent from zero relative to the returns during the middle of the week. However, when we focus on the median regression analysis, the weekend effect is present in the WTI sample and not evident in the Brent sample.

Alternatively, our strong and consistent findings across all estimations for Gas suggest the existence of a "reverse" weekend effect, whereas mean and median Friday returns are negative and strongly significant while mean and median Monday returns are positive and significant regardless of regression estimation contributes to the growing calendar effect literature. Brusa, Liu, and Schulman (2000) are among the first to document the presence of a "reverse" weekend effect in U.S. indices. To the best of our knowledge, this study is the first to document such a calendar anomaly for natural gas.

To investigate whether the weekend effect is persistent or period driven post-1980, we segregate our sample into three approximately equal subperiods. We then replicate our analysis over the various subperiods separately. Using the subperiods, we find that (1) the weekend effect we document for the OLS estimations for WTI is largely driven by the 1997-2006 subperiod, (2) evidence of the weekend effect for WTI using median regression estimation for the two subperiods of 1997-2006 and 2007-2017, (3) the weekend effect found for the Brent robust OLS estimation is primarily driven by the 2007-2017 subperiod, and (4) the "reverse" weekend effect we document for natural gas persists within each of the subperiods and across all estimations.

Data and methodology are presented in the following section. In section III, we present our results and discuss our findings. A summary and concluding remarks are offered in section IV.

II. Data and Methodology

Daily closing spot prices on all three energy commodities (WTI, Brent, and Gas) are obtained from the United States Energy Information Administration (hereafter EIA) website.[2] The EIA reports data for WTI starting January 1986, the data on Brent is available beginning May 1987, and the data for Gas starting in January 1997. The sample period for all data concludes with the last trading day of May 2017.

[2] The EIA data for petroleum is available at the following address: https://www.eia.gov/petroleum/data.php and EIA data for natural gas is available at the following address: https://www.eia.gov/naturalgas/data.php.

Figure 1 plots the daily closing spot prices for all three commodities. Panels A and B of Figure 1 suggest that WTI and Brent prices are positively correlated, as expected, over our sample period. However, we also note that Gas spot prices are not as highly, positively correlated with the two crude oil commodities (See Panel C of Figure 1).

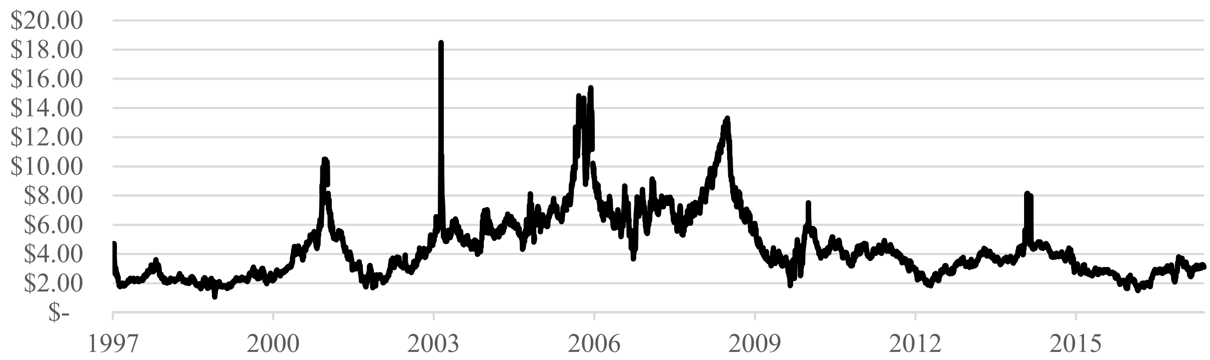
Figure 1: Daily WTI, Gas, and Brent Prices over Sample Period

The figure in Panel A illustrates the time series of the daily spot price (USD per barrel) for WTI (crude oil; Cushing, OK) covering the sample period from January 2, 1986 through May 30, 2017. The figure in Panel B displays the time series of the daily spot price (USD per barrel) for Brent (crude oil; Europe) covering the sample period from May 20, 1987 through May 30, 2017. The figure in Panel C depicts the time series of the daily spot price (USD per MBTU) for Gas (Henry Hub Natural Gas) covering the sample period from January 7, 1997 through May 30, 2017. The data was collected from the U.S. Energy Information Administration (EIA).

Panel A: Daily WTI (USD per barrel) Prices (January 2, 1986 - May 30, 2017)

Panel B: Daily Brent (USD per barrel) Prices (May 20, 1987 - May 30, 2017)

Panel C: Daily Gas (USD per MBTU) Prices (January 7, 1997 - May 30, 2017)



Commodities returns are calculated from each price series as:

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}} \quad (1)$$

where $i = \{\text{WTI}, \text{Brent}, \text{Gas}\}$, $P_{i,t}$ represents commodity *i's* price at time *t* and $P_{i,t-1}$ the commodity's price on the previous trading day. Returns that occur over a holiday and the day following a holiday are excluded, allowing for the return series to represent "normal daily returns."[3] The final sample includes 7,667, 7,441, and 4,945 observations for WTI, Brent, and Gas, respectively. Table 1 presents summary statistics of our daily return series for crude oil and natural gas.

Panel A of Table 1 describes centrality, range, and distribution of our series. We find average daily returns on Gas to be 6.54 basis points (Bps), approximately twice as high as average daily returns on WTI (3.04 Bps) and Brent (3.45 Bps). This pattern of returns is replicated in the second, third, and fourth moments of our return series. However, median returns are positive for WTI (3.13 Bps) while being 0.00 Bps for both Brent and Gas. Panel B shows the correlations for each of the days of our return series.

We report Pearson (below the diagonal) and Spearman (above the diagonal) correlation coefficients for each trading day of the week. Not surprisingly, we find the correlation between WTI and Brent to be much stronger than the correlation between either type of crude oil and Gas. For example, the Pearson correlation coefficient on Monday between WTI and Brent is about 65.39% while the correlation between WTI (Brent) and Gas is 11.00% (16.04%). Of note is the finding that Wednesday and Friday returns for WTI and Gas are not significantly correlated. Levene's test statistics for the returns for the day of the week are reported in Panel C and provide evidence against the null hypothesis of equal variances across days for each commodity. The number of return observations for each day of the week differ due to our data cleaning requirement of two consecutive trading days and excluding dates corresponding with holidays.

[3] To be included in the sample, we require two consecutive trading days for the computation of returns and exclude trading days that correspond to calendar holidays from our sample to reduce any potential bias.

Table 1: Summary Statistics

This table reports the summary statistics for the daily returns of the spot price (USD per barrel) for WTI (crude oil; Cushing, OK) covering the sample period from January 2, 1986 through May 30, 2017, the daily returns of the spot price (USD per barrel) for Brent (crude oil; Europe) covering the sample period from May 20, 1987 through May 30, 2017, and the daily returns of the spot price (USD per MBTU) for Gas (Henry Hub Natural Gas) covering the sample period from January 7, 1997 through May 30, 2017. This data is used throughout the analysis. Panel A reports descriptive statistics of relevant daily return variables. Panel B contains correlation matrices and coefficients for each of the three commodities (WTI, Brent, and Gas) for each day of the week used in the analysis. Correlations reported above the diagonal are Spearman correlations whereas those reported below the diagonal are Pearson correlations. P-values (two-tailed tests) for the coefficients that are less than 1 percent are in bold, less than 5 percent are in bold italics, and less than 10 percent are in italics. Panel C provides the results from the Levene's test of equal variances centered around the means and medians for WTI, Brent, and Gas, respectively. In Panel C, the symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test. The data in the table was collected from the U.S. Energy Information Administration (EIA).

Panel A: Sample Daily Return Descriptive Statistics

Variable	*N*	Mean	S.D.	Skewness	Kurtosis	Min	0.25	Median	0.75	Max
WTI	7,667	0.0304	2.4934	-0.1794	12.9496	-33.3953	-1.2048	0.0313	1.2750	21.1073
Brent	7,441	0.0345	2.2640	-0.1524	12.7051	-30.3170	-1.1192	0.0000	1.1863	18.9262
Gas	4,945	0.0654	4.4577	2.1943	37.8954	-43.3442	-2.0253	0.0000	1.8617	78.0089

Panel B: Correlation Matrix by Day Returns

Monday	**WTI**	**Brent**	**Gas**
WTI		**0.6090**	**0.0915**
Brent	**0.6539**		**0.1945**
Gas	**0.1100**	**0.1604**	

Tuesday	**WTI**	**Brent**	**Gas**
WTI		**0.5155**	**0.1073**
Brent	**0.5274**		**0.2198**
Gas	***0.0717***	**0.1955**	

Wednesday	**WTI**	**Brent**	**Gas**
WTI		**0.5883**	0.0267
Brent	**0.6051**		**0.0811**
Gas	0.0163	***0.0623***	

Thursday	**WTI**	**Brent**	**Gas**
WTI		**0.5383**	*0.0607*
Brent	**0.5801**		**0.1537**
Gas	**0.0902**	**0.1314**	

Friday	**WTI**	**Brent**	**Gas**
WTI		**0.5212**	0.0411
Brent	**0.5580**		**0.1562**
Gas	0.0271	**0.1530**	

Table 1 – *continued*

Panel C: Levene's Test Statistic (Null: Equal Variances)

WTI Daily Returns

Day	Mean	S.D.	*N*
Monday	-0.0973	2.8567	1,433
Tuesday	-0.0609	2.3337	1,495
Wednesday	0.0651	2.5238	1,613
Thursday	0.1397	2.5189	1,585
Friday	0.0892	2.2003	1,541
Total	0.0304	2.4934	7,667
Mean Statistic	**8.1207**	***	
Median Statistic	**8.1114**	***	

Brent Daily Returns

Day	Mean	S.D.	*N*
Monday	-0.0568	2.4988	1,429
Tuesday	-0.0896	2.1175	1,444
Wednesday	0.0128	2.1689	1,531
Thursday	0.2132	2.3686	1,536
Friday	0.0801	2.1372	1,501
Total	0.0345	2.2640	7,441
Mean Statistic	**3.9400**	***	
Median Statistic	**3.9247**	***	

Gas Daily Returns

Day	Mean	S.D.	*N*
Monday	1.0052	5.6247	916
Tuesday	0.5787	4.4540	962
Wednesday	0.3154	3.9488	1,047
Thursday	-0.3348	3.6899	1,027
Friday	-1.1484	4.1632	993
Total	0.0654	4.4577	4,945
Mean Statistic	**10.1965**	***	
Median Statistic	**9.1038**	***	

We follow Lucey and Zhao (2008) and Haggard and Witte (2010) for our analytical investigation of the weekend effect in energy markets. We generally estimate the following parsimonious OLS model:

$$R_{i,t} = \alpha + \beta_1 M_t + \beta_2 F_t + \varepsilon_{i,t} \tag{2}$$

where $R_{i,t}$ is the return on commodity i at time t, M_t and F_t are indicator variables taking the value of "1" for Monday and Friday respectively, and "0" otherwise. Following Haggard and Witte (2010), who show that outliers can account for a significant proportion of calendar anomalies, we consider the effect of outliers and perform Huber (1964) and Hampel (1974) *M-estimation* techniques. For robustness, we perform an additional robust OLS regression estimation that eliminates observations with Cook's distance greater than one prior to iterating with Huber and biweights consecutively as recommended by Li (1985).

Even after attempting to adjust outliers or extreme data observations, we may still find evidence of a weekend anomaly in our data due to OLS regressions estimating the conditional mean function. Therefore, we estimate median (least-absolute-residual) regressions with robust standard errors as described by Koenker and Hallock (2001) and following Haggard, Jones, and Witte (2015). Median regressions are robust to outliers as the regression estimates the conditional median function, resulting in the minimization of absolute deviations from the estimated median. This estimation technique diminishes the impact of any single outlier and the impact of a few outliers is greatly reduced.

III. Empirical Results

Our empirical investigation of the weekend effect in energy markets starts with univariate estimations of equation (2) above where we restrict the parameters β_2 or β_1 to zero. We then allow both parameters to be estimated freely as per the specification of equation (2). This approach allows us to observe the commodities Monday and Friday returns independently before pooling them to investigate the weekend effect in crude oil and natural gas.

Table 2 presents the results of our analyses for WTI over the entire sample period. In Panel A, we report results of our estimations after restricting the parameters β_2 to zero. We find $\beta_1$to be negative and strongly significant across our models. For example, in Model (3), estimated using the Hampel (1974) M-Estimation technique, we find that the average Monday return for WTI is negative and approximately 17.04 Bps lower than other daily returns throughout the week with an approximate t-statistic of about 2.77. The sign and significance of this average Monday return is replicated in models (1), (2), (4), and (5) as well. In Panel B, we restrict the parameter β_1 to zero in estimating equation (2) for WTI. We find across all our estimation methods that, while the mean return on Friday over the sample period generally carries a positive sign, it is also not statistically different from zero.

Lastly, when allowing the parameters in equation (2) to be freely estimated, we find the Monday and Friday return behaviors to replicate those obtained when investigated independently. Specifically, as shown in Panel C of Table 2, we find that, while the mean and median Monday returns over our entire sample remain negative and strongly significant across our estimation methods, that of Friday returns also retains its positive sign and remains insignificant. For instance, in model (5) estimated using the median regression method with robust standard errors, we find that the median Monday return for WTI is negative and significantly 19.89 Bps (t-stat ≈ 2.86) lower than the middle of the week daily returns. Friday returns continue to be flat, statically indifferent from zero (approximately 2.91 Bps; t-stat ≈ 0.51) relative to the returns during the middle of the week.

Table 2: Weekend Effect WTI Regression Analysis

This table contains the results of regression specifications conducted to analyze the weekend effect for WTI (crude oil; Cushing, OK) covering the sample period from January 2, 1986 through May 30, 2017. Panel A and Panel B contain univariate estimations of equation (2) by restricting the parameters β_2 and β_1 to zero, respectively. Panel C provides the results from equation model (2); all equation models are described in the paper. Column 1 is an OLS regression that corrects for heteroskedasticity using White-Huber standard errors. Column 2 is a robust M-Estimation regression using Huber (1964) weight with $c = 1.345$. Column 3 is a robust M-Estimation regression using Hampel (1974) weights with $a = 2$, $b = 4$, and $c = 8$. Column 4 is a robust regression that eliminates gross outliers with a Cook's distance greater than 1 and then performs Huber iterations followed by biweight iterations. Column 5 is a median regression estimation with robust standard errors. In all specifications, the dependent variable is the daily return for WTI and expressed in percentage terms (e.g., 1.45 = 1.45%). Monday and Friday are binary variables that take the value of "1" for Monday and Friday returns, respectively. t-statistics are presented in brackets below the respective coefficients. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test.

Panel A: Monday Effect

	(1)	(2)	(3)	(4)	(5)
Monday	-0.1571*	-0.1645***	-0.1704***	-0.1640***	-0.2081***
	[-1.9310]	[-2.7740]	[-2.7707]	[-2.7743]	[-3.1274]
Intercept	0.0598**	0.0690***	0.0631**	0.0678***	0.0813***
	[1.9657]	[2.6953]	[2.3722]	[2.6549]	[3.0667]
N	7,667	7,667	7,667	7,667	7,667
R^2	0.0006	0.0007	0.0001	0.0010	
adj. R^2	0.0005	0.0006	-0.0001	0.0009	
pseudo R^2					0.0008

Panel B: Friday Effect

	(1)	(2)	(3)	(4)	(5)
Friday	0.0735	0.0690	0.0601	0.0642	0.1012*
	[1.1326]	[1.1958]	[1.005]	[1.1167]	[1.873]
Intercept	0.0157	0.0248	0.0197	0.025	0.0000
	[0.4782]	[0.9575]	[0.7351]	[0.9702]	[0.0000]
N	7,667	7,667	7,667	7,667	7,667
R^2	0.0001	0.0001	0.0000	0.0002	
adj. R^2	0.0000	-0.0001	-0.0002	0.0001	
pseudo R^2					0.0002

Panel C: Monday and Friday Effect (Weekend Effect)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.1474*	-0.1561**	-0.1647***	-0.1565**	-0.1989***
	[-1.7639]	[-2.5548]	[-2.6019]	[-2.5706]	[-2.8688]
Friday	0.0390	0.0335	0.0223	0.0291	0.0291
	[0.5859]	[0.564]	[0.362]	[0.4907]	[0.5181]
Intercept	0.0501	0.0605**	0.0575*	0.0605**	0.0720**
	[1.394]	[2.0508]	[1.8791]	[2.0525]	[2.1923]
N	7,667	7,667	7,667	7,667	7,667
R^2	0.0006	0.0007	0.0001	0.0010	
adj. R^2	0.0004	0.0005	-0.0002	0.0008	
pseudo R^2					0.0008

Overall the evidence reported in Table 2 suggests the existence of a weekend effect in the WTI crude-oil market. The signs of our estimated parameters are consistent with Kohli (2014). Table 2 brings credence to the notion of controlling for outliers as there is only marginal significance with a basic OLS estimation (Model 1). Using robust OLS techniques and the median estimation, we find strong evidence of the weekend effect for WTI.

Next, we repeat the analysis above for Brent and Gas. Table 3 reports the results of this exercise over the entire sample period for Brent, and Table 4 for Gas. We find that the behavior of Brent's mean returns on Monday and Friday, relative to the daily returns during the middle of the week, as shown in Table 3 closely replicate that of WTI reported in Table 2. Brent's Friday mean returns are not statistically different from zero across our estimation techniques (See Panels B and C of Table 3), whereas Monday mean returns are negative and statistically significant in six out of ten models estimated (See Panels A and C of Table 3). The evidence in Table 3 indicates that one would not have found any evidence of a weekend effect for Brent simply by estimating a basic OLS regression. However, once we perform robust OLS techniques to account for outliers in the conditional mean, we find evidence of the weekend effect in the Brent market. Interestingly, this finding is not conclusive as the median regression estimation fails to find evidence of the anomaly. While we find similar evidence using the conditional mean regressions (OLS), this lack of evidence highlights the differences in the data distributions as WTI had an approximate daily median return of 3.13 Bps and Brent's median return was 0.00 Bps.

Table 3: Weekend Effect Brent Regression Analysis

This table contains the results of regression specifications conducted to analyze the weekend effect for Brent (crude oil; Europe) covering the sample period from May 20, 1987 through May 30, 2017. Panel A and Panel B contain univariate estimations of equation (2) by restricting the parameters β_2 and β_1 to zero, respectively. Panel C provides the results from equation model (2); all equation models are described in the paper. Column 1 is an OLS regression that corrects for heteroskedasticity using White-Huber standard errors. Column 2 is a robust M-Estimation regression using Huber (1964) weight with c = 1.345. Column 3 is a robust M-Estimation regression using Hampel (1974) weights with a = 2, b = 4, and c = 8. Column 4 is a robust regression that eliminates gross outliers with a Cook's distance greater than 1 and then performs Huber iterations followed by biweight iterations. Column 5 is a median regression estimation with robust standard errors. In all specifications, the dependent variable is the daily return for Brent and expressed in percentage terms (e.g., 1.45 = 1.45%). Monday and Friday are binary variables that take the value of "1" for Monday and Friday returns, respectively. t-statistics are presented in brackets below the respective coefficients. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test.

Panel A: Monday Effect

	(1)	(2)	(3)	(4)	(5)
Monday	-0.1130	-0.1225**	-0.1289**	-0.1245**	-0.0215
	[-1.5703]	[-2.2032]	[-2.2301]	[-2.2294]	[-0.3642]
Intercept	0.0562**	0.0503**	0.0447*	0.0418*	0.0215
	[1.9773]	[2.0615]	[1.7598]	[1.7067]	[0.8803]
N	7,441	7,441	7,441	7,441	7,441
R^2	0.0004	0.0005	0.0005	0.0007	
adj. R^2	0.0003	0.0004	0.0004	0.0006	
pseudo R^2					0.0000

Panel B: Friday Effect

	(1)	(2)	(3)	(4)	(5)
Friday	0.0572	0.0523	0.0571	0.0512	0.0483
	[0.9118]	[0.9561]	[1.0053]	[0.9345]	[0.9127]
Intercept	0.0230	0.0168	0.0091	0.0082	0.0000
	[0.772]	[0.6829]	[0.3569]	[0.3336]	[0.0000]
N	7,441	7,441	7,441	7,441	7,441
R^2	0.0001	0.0001	0.0000	0.0001	
adj. R^2	-0.0001	-0.0001	-0.0002	-0.0001	
pseudo R^2					0.0001

Panel C: Monday and Friday Effect (Weekend Effect)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.1050	-0.1161**	-0.1217**	-0.1184**	-0.0104
	[-1.4202]	[-2.0191]	[-2.0385]	[-2.0559]	[-0.1726]
Friday	0.0319	0.0251	0.0285	0.0237	0.0379
	[0.4956]	[0.4450]	[0.4863]	[0.4197]	[0.6930]
Intercept	0.0482	0.0439	0.0375	0.0357	0.0104
	[1.4556]	[1.5567]	[1.2799]	[1.2627]	[0.3805]
N	7,441	7,441	7,441	7,441	7,441
R^2	0.0004	0.0005	0.0005	0.0007	
adj. R^2	0.0002	0.0003	0.0003	0.0005	
pseudo R^2					0.0001

Perhaps more interesting is our finding of a "reverse" weekend effect for Gas returns. We generally find that Friday mean returns on Gas are negative and strongly significant while the Monday mean returns are positive and strongly significant relative to daily returns from the rest of the week. Specifically, we find in all estimated models including the Monday variable that Monday mean returns are positively significant at the one percent level of confidence. The mean Monday return coefficients vary between 38.63 Bps and 115.34 Bps across our estimated OLS models and the median Monday return coefficient is approximately 37.17 Bps (See Panels A and C of Table 4). Similarly, all the estimated models including the Friday variable show that the Friday returns on Gas are significantly negative relative to the rest of the week. Estimated Friday mean return coefficients vary between -151.88 Bps and -102.00 Bps and the median Friday return coefficient is approximately -90.09 Bps (See Panels B and C of Table 4) lower relative to the middle of the week.

Table 4: Weekend Effect Gas Regression Analysis

This table contains the results of regression specifications conducted to analyze the weekend effect for Gas (Henry Hub Natural Gas) covering the sample period from January 7, 1997 through May 30, 2017. Panel A and Panel B contain univariate estimations of equation (2) by restricting the parameters β_2 and β_1 to zero, respectively. Panel C provides the results from equation model (2); all equation models are described in the paper. Column 1 is an OLS regression that corrects for heteroskedasticity using White-Huber standard errors. Column 2 is a robust M-Estimation regression using Huber (1964) weight with c = 1.345. Column 3 is a robust M-Estimation regression using Hampel (1974) weights with a = 2, b = 4, and c = 8. Column 4 is a robust regression that eliminates gross outliers with a Cook's distance greater than 1 and then performs Huber iterations followed by biweight iterations. Column 5 is a median regression estimation with robust standard errors. In all specifications, the dependent variable is the daily return for Gas and expressed in percentage terms (e.g., 1.45 = 1.45%). Monday and Friday are binary variables that take the value of "1" for Monday and Friday returns, respectively. t-statistics are presented in brackets below the respective coefficients. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test.

Panel A: Monday Effect

	(1)	(2)	(3)	(4)	(5)
Monday	1.1534***	0.7191***	0.7436***	0.6286***	0.3717***
	[5.8614]	[6.0684]	[6.1151]	[5.3913]	[2.8029]
Intercept	-0.1483**	-0.1674***	-0.1738***	-0.1666***	0.0000
	[-2.2851]	[-3.2824]	[-3.3231]	[-3.3208]	[0.0000]
N	4,945	4,945	4,945	4,945	4,945
R^2	0.0101	0.0048	0.0019	0.0058	
adj. R^2	0.0099	0.0046	0.0017	0.0056	
pseudo R^2					0.0007

Table 4 – *continued*

Panel B: Friday Effect

	(1)	(2)	(3)	(4)	(5)
Friday	-1.5188***	-1.2091***	-1.2306***	-1.1038***	-0.9009***
	[-10.1215]	[-10.6155]	[-10.5179]	[-9.8397]	[-6.5345]
Intercept	0.3704***	0.1942***	0.2012***	0.1534***	0.0000
	[5.1998]	[3.8078]	[3.8397]	[3.0516]	[0.0000]
N	4,945	4,945	4,945	4,945	4,945
R^2	0.0186	0.0149	0.0043	0.0192	
adj. R^2	0.0185	0.0148	0.0041	0.0191	
pseudo R^2					0.0059

Panel C: Monday and Friday Effect (Weekend Effect)

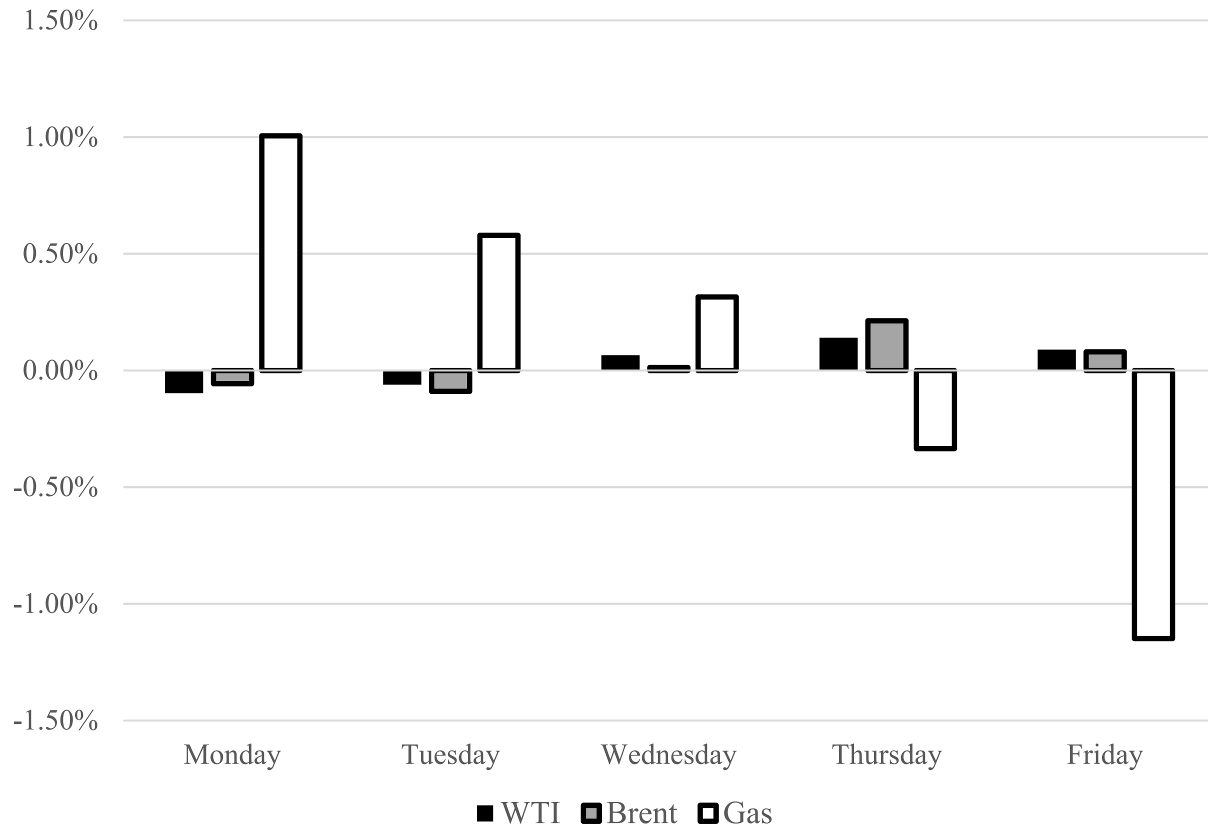
	(1)	(2)	(3)	(4)	(5)
Monday	0.8263***	0.4543***	0.4681***	0.3863***	0.3717***
	[4.1353]	[3.7514]	[3.7750]	[3.2440]	[2.7899]
Friday	-1.3273***	-1.1101***	-1.1255***	-1.0200***	-0.9009***
	[-8.7803]	[-9.4557]	[-9.3558]	[-8.8318]	[-6.4634]
Intercept	0.1789**	0.0952	0.0972	0.0706	0.0000
	[2.4331]	[1.6329]	[1.6281]	[1.2306]	[0.0000]
N	4,945	4,945	4,945	4,945	4,945
R^2	0.0235	0.0167	0.0054	0.0215	
adj. R^2	0.0232	0.0164	0.0050	0.0212	
pseudo R^2					0.0066

Overall, the evidence reported in Table 4 suggests the existence of a "reverse" weekend effect in natural gas returns. Unlike the weekend effect of Fields (1931) or French (1980), where Monday returns are shown to be negative and significant and Friday returns are generally positive, we find that Friday returns for Gas tend to be negative and strongly significant while Monday returns carry positive signs and are statistically different from zero. This finding is consistent with Brusa, Liu, and Schulman (2000) whom document the presence of a "reverse" weekend effect in U.S. indices

Figure 2 presents average returns for each day of the week for each commodity. Consistent with our earlier findings, this figure shows negative Monday and positive Friday mean returns for WTI and Brent. The Monday and Friday mean returns on Gas are positive and negative, respectively. More evident in this figure are the differences in magnitudes of daily returns across the commodities, an observation consistent with the differences in price volatilities reported in Table 1.

Figure 2: Daily WTI, Gas, and Brent Returns in Percent by Day

This figure displays the average daily return data for the following: 1) The average daily return by day for WTI (crude oil; Cushing, OK) covering the sample period from January 2, 1986 through May 30, 2017, 2) the average daily return by day for Brent (crude oil; Europe) covering the sample period from May 20, 1987 through May 30, 2017, and 3) the mean daily return by day for Gas (Henry Hub Natural Gas) covering the sample period from January 7, 1997 through May 30, 2017. The data was collected from the U.S. Energy Information Administration (EIA).



Evidence reported by Connolly (1989) and Chang et al. (1993) and later supported by the findings of Kamara (1997) and Chen and Singal (2003) suggest that the weekend effect disappears in equity markets post-1980. However, our results for a post-1980 sample period show that the weekend effect exists in crude oil in general, and unique to natural gas, there is evidence of a "reverse" weekend. Nevertheless, the question of whether the weekend effect we document in this study disappears sometime post-1980 remains open. To address this concern, we split our sample into three equal subperiods and replicate our analysis for each of the subperiods. We report the results of our estimations of equation (2) above when both parameters β_2 and β_1 are estimated freely.

Table 5 shows the subperiod results for WTI. There is no evidence of any weekend effect for the first subperiod of 1986 through 1996 (Panel A). Subsequently, for WTI, the weekend effect we document using robust OLS techniques in this study is largely driven by the behavior of WTI prices during the 1997-2006 subperiod. However, if we shift focus from the conditional mean to the conditional median, we find evidence of the weekend for both the subperiods of 1997-2006 and 2007-2017 using the median regression estimation. Collectively, without the median estimation, we might have incorrectly claimed to find no weekend effect for the last subperiod. In Panel C, only the median estimation provides negative (-23.62 Bps) and significant (t-stat ≈ -2.21) median Monday returns. However, the corresponding mean Friday return is also negative (-2.84 Bps) and insignificant (t-stat ≈ -0.26). On the other hand, when investigating the subperiod of 1997 to 2006, we find robust evidence of a weekend effect. Four out of five models (all robust OLS and median regression techniques) estimated report significantly negative mean and median Monday returns while five out of five models estimated report positively significant mean and median Friday returns (See Panel B of Table 5).

Table 5: Weekend Effect WTI Regression Analysis Subperiods

This table contains the results of regression specifications conducted to analyze the weekend effect for WTI (crude oil; Cushing, OK) covering three sample subperiods from January 2, 1986 through May 30, 2017. Panels A, B, and C provide the results from equation model (2) as described in the paper. Panel A covers the period of January 2, 1986 through December 31, 1996, Panel B includes the period of January 2, 1997 through December 29, 2006, and Panel C comprises the period of January 2, 2007 through May 30, 2017. Column 1 is an OLS regression that corrects for heteroskedasticity using White-Huber standard errors. Column 2 is a robust M-Estimation regression using Huber (1964) weight with c = 1.345. Column 3 is a robust M-Estimation regression using Hampel (1974) weights with a = 2, b = 4, and c = 8. Column 4 is a robust regression that eliminates gross outliers with a Cook's distance greater than 1 and then performs Huber iterations followed by biweight iterations. Column 5 is a median regression estimation with robust standard errors. In all specifications, the dependent variable is the daily return for WTI and expressed in percentage terms (e.g., 1.45 = 1.45%). Monday and Friday are binary variables that take the value of "1" for Monday and Friday returns, respectively. t-statistics are presented in brackets below the respective coefficients. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test.

Panel A: Monday and Friday Effect (Weekend Effect; 1986-1996)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.0283	-0.0126	-0.0132	-0.0078	-0.0530
	[-0.1856]	[-0.1348]	[-0.1352]	[-0.0849]	[-0.4823]
Friday	-0.1102	-0.0398	-0.0852	-0.0303	-0.0530
	[-1.0031]	[-0.4336]	[-0.8894]	[-0.3342]	[-0.5601]
Intercept	0.0510	0.0553	0.0580	0.0499	0.0530
	[0.8576]	[1.2101]	[1.2159]	[1.1048]	[1.1039]
N	2,725	2,725	2,725	2,725	2,725
R^2	0.0003	0.0000	0.0011	0.0000	
adj. R^2	-0.0005	-0.0008	0.0004	-0.0008	
pseudo R^2					0.0002

Table 5 – *continued*

Panel B: Monday and Friday Effect (Weekend Effect; 1997-2006)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.2027	-0.3192***	-0.3179***	-0.3611***	-0.3623**
	[-1.3641]	[-2.638]	[-2.6382]	[-3.0222]	[-2.2166]
Friday	0.2884**	0.2582**	0.2517**	0.2438**	0.2024*
	[2.4747]	[2.2182]	[2.1717]	[2.1206]	[1.8208]
Intercept	0.0262	0.0735	0.0702	0.0899	0.0858
	[0.4107]	[1.2716]	[1.2188]	[1.5738]	[1.2838]
N	2,413	2,413	2,413	2,413	2,413
R2	0.0039	0.0051	0.0000	0.0073	
adj. R^2	0.0031	0.0043	-0.0009	0.0065	
pseudo R^2					0.0041

Panel C: Monday and Friday Effect (Weekend Effect; 2007-2017)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.2278*	-0.1556	-0.1631	-0.1259	-0.2362**
	[-1.7481]	[-1.4638]	[-1.4747]	[-1.1901]	[-2.2192]
Friday	-0.0397	-0.0694	-0.0677	-0.0906	-0.0284
	[-0.3322]	[-0.6712]	[-0.6292]	[-0.8799]	[-0.2637]
Intercept	0.0722	0.0499	0.0383	0.0412	0.0702
	[1.1292]	[0.9708]	[0.7159]	[0.8057]	[1.1845]
N	2,529	2,529	2,529	2,529	2,529
R2	0.0012	0.0006	0.0001	0.0007	
adj. R^2	0.0005	-0.0002	-0.0007	-0.0001	
pseudo R^2					0.0008

Shifting our focus to the Brent sample, we find no apparent evidence of the weekend effect for returns during subperiod of 1987 through 1996. There is marginal evidence of positive Friday returns during the second subperiod (1997-2006) in Models 3 through 5. In the final subperiod (2007-2017), there is marginal evidence of negative Monday and Friday returns. Collectively, even though we found evidence of a weekend effect for the conditional means over the entire sample period, there is little to no evidence consistent with the existence of a weekend effect when splitting our sample period (See Panels A, B, and C of Table 6).

Remarkably, our results from this exercise with Gas over the sub-sample periods closely resemble our findings using the entire sample. That is, over the period from 1997 to 2006, four out of five models report evidence consistent with our "reverse" weekend effect. Over the final period from 2007 through 2017, all estimated models suggest the existence of the "reverse" weekend effect. The evidence for Gas provided in Table 7 is robust across different estimation techniques and does not appear to be driven by any return outliers in the data.

Table 6: Weekend Effect Brent Regression Analysis Subperiods

This table contains the results of regression specifications conducted to analyze the weekend effect for Brent (crude oil; Europe) covering the sample period from May 20, 1987 through May 30, 2017. Panels A, B, and C provide the results from equation model (2) as described in the paper. Panel A covers the period of May 20, 1987 through December 31, 1996, Panel B includes the period of January 2, 1997 through December 29, 2006, and Panel C comprises the period of January 2, 2007 through May 30, 2017. Column 1 is an OLS regression that corrects for heteroskedasticity using White-Huber standard errors. Column 2 is a robust M-Estimation regression using Huber (1964) weight with c = 1.345. Column 3 is a robust M-Estimation regression using Hampel (1974) weights with a = 2, b = 4, and c = 8. Column 4 is a robust regression that eliminates gross outliers with a Cook's distance greater than 1 and then performs Huber iterations followed by biweight iterations. Column 5 is a median regression estimation with robust standard errors. In all specifications, the dependent variable is the daily return for Brent and expressed in percentage terms (e.g., 1.45 = 1.45%). Monday and Friday are binary variables that take the value of "1" for Monday and Friday returns, respectively. t-statistics are presented in brackets below the respective coefficients. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test.

Panel A: Monday and Friday Effect (Weekend Effect; 1987-1996)

	(1)	(2)	(3)	(4)	(5)
Monday	0.0061	-0.0409	-0.0383	-0.0494	0.0000
	[0.0457]	[-0.4767]	[-0.4299]	[-0.5795]	[0.0000]
Friday	0.0630	0.0727	0.0746	0.0829	0.1760*
	[0.6018]	[0.8634]	[0.8535]	[0.9914]	[1.9101]
Intercept	0.0140	0.0206	0.0103	0.0128	0.0000
	[0.2472]	[0.4882]	[0.2352]	[0.3042]	[0.0000]
N	2,402	2,402	2,402	2,402	2,402
R2	0.0001	0.0003	0.0001	0.0007	
adj. R^2	-0.0008	-0.0006	-0.0008	-0.0002	
pseudo R^2					0.0008

Panel B: Monday and Friday Effect (Weekend Effect; 1997-2006)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.1832	-0.1435	-0.1473	-0.1316	-0.0742
	[-1.3578]	[-1.2265]	[-1.2644]	[-1.1270]	[-0.5672]
Friday	0.1898	0.1894	0.1898*	0.1933*	0.2232*
	[1.6388]	[1.6412]	[1.6519]	[1.6782]	[1.8435]
Intercept	0.0571	0.0539	0.0457	0.0507	0.0188
	[0.9267]	[0.9341]	[0.7948]	[0.8795]	[0.2931]
N	2,499	2,499	2,499	2,499	2,499
R2	0.0024	0.0019	0.0005	0.0021	
adj. R^2	0.0017	0.0012	-0.0004	0.0014	
pseudo R^2					0.0016

Panel C: Monday and Friday Effect (Weekend Effect; 2007-2017)

	(1)	(2)	(3)	(4)	(5)
Monday	-0.1324	-0.1672*	-0.1841*	-0.1879**	-0.1193
	[-1.1474]	[-1.7712]	[-1.8447]	[-1.9769]	[-1.3018]
Friday	-0.1534	-0.1705*	-0.1776*	-0.1781*	-0.1390*
	[-1.3603]	[-1.8472]	[-1.8215]	[-1.9181]	[-1.8541]
Intercept	0.0717	0.0641	0.0528	0.0474	0.0652
	[1.3283]	[1.3965]	[1.0887]	[1.0260]	[1.5305]
N	2,540	2,540	2,540	2,540	2,540
R2	0.0010	0.0015	0.0004	0.0024	

adj. R^2	0.0003	0.0008	-0.0004	0.0017	
pseudo R^2					0.0009

Table 7: Weekend Effect Gas Regression Analysis Subperiods

This table contains the results of regression specifications conducted to analyze the weekend effect for Gas (Henry Hub Natural Gas) covering two sample subperiods from January 7, 1997 through May 30, 2017. Panels A and B provide the results from equation model (2) as described in the paper. Panel A covers the period of January 7, 1997 through December 29, 2006 and Panel B includes the period of January 2, 2007 through May 30, 2017. Column 1 is an OLS regression that corrects for heteroskedasticity using White-Huber standard errors. Column 2 is a robust M-Estimation regression using Huber (1964) weight with c = 1.345. Column 3 is a robust M-Estimation regression using Hampel (1974) weights with a = 2, b = 4, and c = 8. Column 4 is a robust regression that eliminates gross outliers with a Cook's distance greater than 1 and then performs Huber iterations followed by biweight iterations. Column 5 is a median regression estimation with robust standard errors. In all specifications, the dependent variable is the daily return for Gas and expressed in percentage terms (e.g., 1.45 = 1.45%). Monday and Friday are binary variables that take the value of "1" for Monday and Friday returns, respectively. t-statistics are presented in brackets below the respective coefficients. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a 2-tailed test.

Panel A: Monday and Friday Effect (Weekend Effect; 1997-2006)

	(1)	(2)	(3)	(4)	(5)
Monday	0.7994**	0.3866**	0.4319**	0.2866	0.3106*
	[2.4747]	[1.9836]	[2.1606]	[1.4912]	[1.7117]
Friday	-1.2302***	-0.9969***	-1.0385***	-0.8911***	-0.9009***
	[-5.1063]	[-5.3196]	[-5.4032]	[-4.8218]	[-3.8208]
Intercept	0.2100*	0.1057	0.1065	0.0765	0.0000
	[1.7720]	[1.1378]	[1.1175]	[0.8348]	[0.0000]
N	2,396	2,396	2,396	2,396	2,396
$R2$	0.0167	0.0110	0.0059	0.0126	
adj. R^2	0.0159	0.0102	0.0051	0.0118	
pseudo R^2					0.0049

Panel B: Monday and Friday Effect (Weekend Effect; 2007-2017)

	(1)	(2)	(3)	(4)	(5)
Monday	0.8520***	0.5188***	0.5140***	0.4628***	0.4329**
	[3.4987]	[3.4842]	[3.3204]	[3.123]	[2.5051]
Friday	-1.4187***	-1.2034***	-1.2117***	-1.1296***	-0.9042***
	[-7.6257]	[-8.2651]	[-8.0086]	[-7.8004]	[-4.9027]
Intercept	0.1493*	0.0879	0.0902	0.067	0.0000
	[1.6812]	[1.2141]	[1.1995]	[0.9302]	[0.0000]
N	2,549	2,549	2,549	2,549	2,549
$R2$	0.0341	0.0247	0.0088	0.0332	
adj. R^2	0.0334	0.0240	0.0081	0.0325	
pseudo R^2					0.0087

IV. Conclusion

While researchers have increasingly sought to document and understand calendar anomalies in the equity market, little attention has been paid to documenting similar evidence in the commodities markets. This study makes several contributions to the body of the literature on the weekend effect in commodities. First, using five different regression estimation techniques and data from the United States Energy Information Administration website, we provide robust evidence of the existence of the weekend effect for two major benchmark crude oil commodities (WTI and Brent). While our analyses suggest that the weekend effect for WTI is largely driven by the 1997-2006 subperiod, there is only marginal evidence of the weekend effect for Brent across subperiods.

Second, we document the existence of a "reverse" weekend effect for Gas. Specifically, we find mean and median Friday returns to be negative and strongly significant while mean and median Monday returns are positive and significant. We show with subperiod analyses that the "reverse" weekend effect we document persists over time, suggesting that further investigation on the behavior of natural gas returns could be a fruitful avenue for future research. Finally, we add to prior studies demonstrating the importance of accounting for outliers in return data.

Overall, our study reveals that the calendar anomaly we investigate for the commodities market manifests itself in a variety of ways depending on the underlying commodity. Our results also present a challenge for the validity of the efficient market hypothesis in the commodities market. We suggest that the following questions remain open and warrant further research: (1) Do explanations of calendar anomalies in equity markets carry over to commodities markets? (2) What underlying characteristic of the commodities yields the observed disparity in the manifestation of the weekend effect documented in this study? And perhaps more interestingly, why do these anomalies persist in the commodities market?

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