Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 15 (XXX), number 4, 2015: 62–70

Anna Górska[1]
Department of Agricultural Economics and International Economic Relations
Monika Krawiec[2]
Department of Econometrics and Statistics,
Warsaw University of Life Sciences – SGGW

Calendar Effects in the Market of Crude Oil

Abstract. This paper investigates calendar effects in the crude oil market using daily data over the period January 4, 2000 to December 31, 2014 for two global oil pricing benchmarks: West Texas Intermediate (WTI) and Brent. Results of performing statistical tests of equality of two means and of equality of two variances reveal the presence of both day-of-the week and month-of-the-year effects.

Key words: crude oil, WTI, Brent, day-of-the-week effect, month-of-the-year effect

Introduction

Oil is one of the newest raw materials, dating back 150 years. In the middle of the 19th Century, Americans searching for new sources of lamp oil discovered liquid petroleum. The raw material for crude oil arose from the remnants of algae and plankton, deposited on underwater seabeds as they died. Over millions of years, deoxygenation occurred, and combined with water pressure, the host rock arose. From that organic material, at depths of 1,500 meters and temperatures of 100 to 150 degrees Celsius, were the components of today's oil deposits. The light components of oil advanced up the earth's surface, and formed oil slate and oil sand [Eller and Sagerer 2008].

The term "crude oil" does not really describe any specific type of oil, but rather the generic state of oils prior their refinement. When extracted from the ground, crude oil may be a pale straw-colored liquid or a thick tar-like substance. Moreover, oil is not a homogenous product as there are about 250 different types of crude oil with different chemical characteristics. The value of crude oil lies in what can be produced from the refining process. The following products are usually produced [Schofield 2007]: gasoline, jet fuel, diesel fuel, asphalt.

Over the past 30 years oil has become the biggest commodity market in the world and has attracted a wide range of participants. They are investment banks, asset managers for mutual funds, pension funds and endowments, insurance companies, hedge funds, traditional oil majors like BP or Total, independents and physical oil traders [Geman 2007]. All those oil market participants and policy makers are interested in recognizing some patterns and anomalies in behavior of oil prices and returns. Such anomalies are calendar effects. The best known are the day-of-the-week effect and the month-of-the-year effect. Both of them are the most frequently investigated seasonal anomalies in stock markets. Studies show that Monday and Friday returns differ from returns on other weekdays: Monday returns are statistically significantly negative, whereas Friday returns are positive.

[1] Ph.D., e-mail: anna_gorska@sggw.pl
[2] Ph.D., e-mail: krawiec.monika@gmail.com

Another well-documented anomaly is the January effect. It is proved that returns on stock markets often are much higher in January than in other months. Other monthly effects are: May effect (low returns) and September effect (high returns).

Although these issues are continuously being reexamined and explored using different methodologies, most works focus on financial markets and it appears that very little attention has been paid to the calendar effects in commodity markets. The most common investigations of calendar effects in commodity markets refer to gold (see [Ball *et al.* 1982], [Ma 1986], [Coutts and Sheikh 2000], [Lucey and Tully 2006], [Yu and Shih 2011], [Qi and Wang 2013], [Górska and Krawiec 2014]), and sometimes to agricultural commodities (see [Lee *et al*. 2013] or [Borowski and Lukasik 2015]). Little work has been done on calendar effects in the crude oil market (see paper by Olowe [2010] examining the month-of-the-year effect or paper by Yu and Shih [2011] examining the weekend effect in the oil market). Our paper is an attempt to fill the gap. Its aim is to search for both weekday and month effects in the crude oil market using statistical tests of equality of two means and of equality of two variances. The paper is organized as follows: The next two sections present the data, methodology, and the results obtained. Finally, the last section provides a brief discussion and conclusions.

Data and Methodology

The empirical data covers daily closing prices of crude oil in USD per barrel from January 4, 2000 to December 31, 2014 from the Bloomberg database (www.bloomberg.com). They are displayed in Figure 1. The West Texas Intermediate (USA origin) and Brent (North West Europe origin) crude oil prices are chosen to represent the oil market as they are key global marker crudes that are used as pricing benchmarks.

During the period under consideration WTI traded between a low of \$17.45 (November 15, 2001) and a high of \$145.29 (July 3, 2008) per barrel, while Brent traded between a low of \$17.68 (November 15, 2001) and a high of \$146.08 (July 3, 2008) per barrel. In Figure 1, there are also displayed the continuously compounded daily returns of oil spot price (r_t) defined as:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

where P_t and P_{t-1} denote the crude oil spot prices at time t and $t-1$.

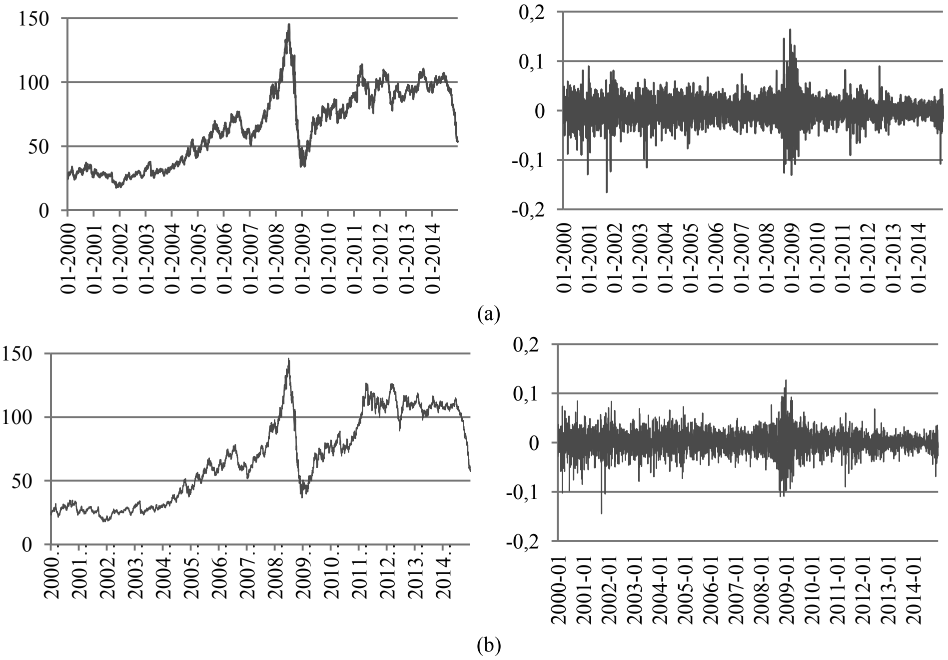

Fig. 1. Oil prices in the period from January 4, 2000 to December 31, 2014 and their logarithmic returns: WTI (a), Brent (b)

Source: own elaboration.

The simplest way to detect calendar effects is to run the test of equality of two means and to verify

H_0: $E(r_1) = E(r_2)$

against

H_1: $E(r_1) \neq E(r_2)$.

The test statistic is given by [Osińska 2006]:

$$z = \frac{\bar{r}_1 - \bar{r}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}, \tag{2}$$

where $\bar{r}_1$ is the arithmetic mean calculated for sample 1 (for example Monday returns), $\bar{r}_2$ is the arithmetic mean calculated for sample 2 (for example Tuesday returns), S_1^2 is the variance calculated for the first sample (Monday returns), S_2^2 is the variance calculated for the second sample (Tuesday returns), n_1 and n_2 are the numbers of observations, respectively in the first and the second samples. For large samples, z-statistic follows normal distribution.

Investigating calendar effects in relation to risk is based on testing equality of two variances:

H_0: $\sigma_1^2 = \sigma_2^2$

against

H_1: $\sigma_1^2 > \sigma_2^2$.

The test statistic is given by [Witkowska *et al.* 2008]:

$$F = \frac{\max(S_1^2, S_2^2)}{\min(S_1^2, S_2^2)} = \frac{S_1^2}{S_2^2}. \tag{3}$$

The statistic has F-distribution with ($n_1 - 1$) and ($n_2 - 1$) degrees of freedom.

Results

The first part of the research aims at investigating the day-of-the week effects. In table 1, there are given values of mean and variance calculated for separate weekdays. Both, WTI and Brent exhibit negative Monday and Tuesday returns (Monday Brent return is the most negative return: -0.001701). WTI also provides negative Wednesday return. The most positive return is Friday WTI return (0.001731). The highest variance appears for WTI on Wednesday (0.000682), the lowest for Brent on Friday (0.000381).

Table 1. Means and variances calculated for separate weekdays

Weekday	WTI			Brent		
	Number of observations	Mean	Variance	Number of observations	Mean	Variance
Monday	782	-0.000943	0.000561	782	-0.001701	0.000476
Tuesday	782	-0.000624	0.000476	783	-0.000220	0.000402
Wednesday	784	-0.000042	0.000682	783	0.000243	0.000519
Thursday	782	0.000818	0.000544	782	0.001513	0.000461
Friday	782	0.001731	0.000441	782	0.001221	0.000381

Source: own calculations.

To detect the day-of-the-week effects we verify a series of hypotheses for all possible pairs of weekdays. In Table 2 there are displayed estimates of z-statistic whereas Table 3 presents estimates of F-statistic.

Table 2. Estimates of z-statistic for weekdays

Weekday	z -statistic	
	WTI	Brent
Monday-Tuesday	-0.2766	-1.3977
Monday-Wednesday	-0.7149	-1.7240
Monday-Thursday	-1.4810	-2.9363*
Monday-Friday	-2.3617*	-2.7928*
Tuesday-Wednesday	-0.4788	-0.4270
Tuesday-Thursday	-1.2627	-1.6499
Tuesday-Friday	-2.1748*	-1.4411
Wednesday-Thursday	-0.6869	-1.1347
Wednesday-Friday	-1.4801	-0.9122
Thursday-Friday	-0.8136	0.2815

Note: * indicates rejection of null hypothesis at 0.05

Source: own calculations.

Results in Table 2 demonstrate that Brent Monday returns differ significantly from Thursday and Friday returns, whereas WTI Monday and Tuesday returns are significantly different from Friday returns.

Table 3. Estimates of F-statistic for weekdays

Weekday	F -statistic	
	WTI	Brent
Monday-Tuesday	1.1791*	1.1817*
Monday-Wednesday	1.2164*	1.0921
Monday-Thursday	1.0316	1.0306
Monday-Friday	1.2720*	1.2497*
Tuesday-Wednesday	1.4342*	1.2905*
Tuesday-Thursday	1.1430*	1.1467*
Tuesday-Friday	1.0788	1.0575
Wednesday-Thursday	1.2547*	1.1254*
Wednesday-Friday	1.5472*	1.3647*
Thursday-Friday	1.2331*	1.2126*

Note: * indicates rejection of null hypothesis at 0.05

Source: own calculations.

Estimates in Table 3 show that WTI Monday variance differs significantly from Tuesday, Wednesday and Friday variances, WTI Tuesday variance differs significantly from Wednesday and Thursday variances, WTI Wednesday variance is significantly different from Thursday and Friday variances, and WTI Thursday variance differs significantly from Friday variance. Brent exhibits similar results except for Monday – Wednesday, where we cannot reject the null hypothesis.

The analogous procedures were applied to test the month-of-the-year effects. In Table 4, there are given values of mean and variance calculated for separate months. WTI and Brent exhibit September through December negative returns. The most negative is October Brent return (-0.00162), while the most positive is February WTI return (0.00252). The highest variance is December WTI variance (0.00083), the lowest is Brent July variance (0.00028).

Table 4. Means and variances calculated for separate months

Month	WTI			Brent		
	Number of observations	Mean	Variance	Number of observations	Mean	Variance
January	332	0.00071	0.00065	332	0.00101	0.00042
February	303	0.00252	0.00052	303	0.00249	0.00039
March	331	0.00096	0.00060	331	0.00066	0.00056
April	321	0.00028	0.00049	321	0.00078	0.00035
May	334	0.00058	0.00042	334	0.00080	0.00036
June	320	0.00129	0.00044	320	0.00100	0.00044
July	332	0.00049	0.00035	332	0.00056	0.00028
August	333	0.00049	0.00037	333	0.00082	0.00032
September	320	-0.00132	0.00070	320	-0.00145	0.00052
October	334	-0.00155	0.00050	334	-0.00162	0.00050
November	321	-0.00131	0.00065	321	-0.00118	0.00060
December	331	-0.00073	0.00083	331	-0.00119	0.00065

Source: own calculations.

In Table 5 there are displayed only those of 132 estimates (66 for WTI and 66 for Brent) of z-statistic that indicate rejection of null hypothesis at 0.05. Analogously, in Table 6 there are demonstrated only the estimates of F-statistic implying rejection of null hypothesis at 0.05.

Table 5. Estimates of z-statistic for months indicating rejection of null hypothesis at 0.05

Month	z-statistic	
	WTI	Brent
February - September	x	2.30829
February - October	2.27121	2.46687
February - November	1.98209	2.06311
February - December	x	2.04546

Source: own calculations.

Results in Table 5 indicate that Brent February returns differ significantly from September, October, November and December returns, while WTI February returns are significantly different from October and November returns.

Table 6. Estimates of F-statistic for months indicating rejection of null hypothesis at 0.05

Month	F-statistic	
	WTI	Brent
January - February	1.2489	x
January - March	x	1.3312
January - April	1.3167	1.2176
January - May	1.5525	x
January - June	1.4793	x
January - July	1.8645	1.4912
January - August	1.7451	1.3321
January - September	x	1.2365
January - October	1.2826	x
January - November	x	1.4255
January - December	1.2906	1.5293
February - March	x	1.4453
February - May	1.2430	x
February - July	1.4929	1.3736
February - August	1.3973	1.2270
February - September	1.3519	1.3424
February - October	x	1.2801
February - November	1.2551	1.5475
February - December	1.6119	1.6603
March - April	1.2243	1.6210
March - May	1.4435	1.5838
March - June	1.3755	1.2930
March - July	1.7337	1.9852
March - August	1.6227	1.7734
March - December	1.3880	x
April - June	x	1.2536
April - July	1.4160	1.2247
April - August	1.3254	x
April - September	1.4253	1.5056
April - October	x	1.4357
April - November	1.3232	1.7357
April - December	1.6993	1.8621
May - June	x	1.2249
May - July	1.2010	1.2534
May - September	1.6805	1.4711

(continued)

Table 6. (continued)

May - October	1.2104	1.4029
May - November	1.5601	1.6959
May - December	2.0036	1.8195
June - July	1.2604	1.5353
June - August	x	1.3715
June - September	1.6013	x
June - November	1.4866	1.3845
June - December	1.9092	1.4854
July - September	2.0183	1.8439
July - October	1.4537	1.7583
July - November	1.8737	2.1257
July - December	2.4063	2.2805
August - September	1.8891	1.6472
August - October	1.3607	1.5707
August - November	1.7538	1.8989
August - December	2.2523	2.0372
September - October	1.3883	x
September - December	x	1.2368
October - November	1.2889	1.2089
October - December	1.6553	1.2970
November - December	1.2843	x

Source: own calculations.

Although detailed results for WTI and Brent, exhibited in Table 6, are slightly different, in most cases there are similar conclusions for both of them. After selecting only those results where the null hypothesis is rejected for both WTI and Brent, we can observe that WTI and Brent January variances are significantly different from April, July, August and December variances. February WTI and Brent variances differ significantly from July, August, September, November and December variances. March WTI and Brent variances are different from April, May, June, July and August variances. April WTI and Brent variances are different from July, September, November and December variances. Then, May WTI and Brent variances are different from July, September, October, November and December variances. June WTI and Brent variances differ from November and December variances only. July and August WTI and Brent variances are different from September to December variances. Finally, October WTI and Brent variances are significantly different from November and December variances.

Concluding remarks

In this paper we examine calendar effects in the crude oil market using daily data over the period January 4, 2000 to December 31, 2014. The two global oil pricing benchmarks: West Texas Intermediate and Brent are chosen for the purpose of the research. In order to detect calendar effects in oil daily logarithmic returns we run two basic statistical tests: the test of equality of two means and the test of equality of two variances.

The results of testing equality of two means show the existence of traditional Monday and Friday effects in oil returns. The results are different from findings of Yu and Shih [2011], who revealed a Wednesday effect in the oil market. However, their study, limited to WTI, covers a different period (January 1, 1986 to December 31, 2007) and uses different methodology (a probability distribution approach). Moreover, our results of testing equality of two means demonstrate that a January effect does not appear. Instead, a February effect occurs. These conclusions differ from those of Olowe [2010] who suggests that monthly seasonal effect is absent in the oil price return series. Again, his examination, limited to Brent, covers a different period (January 4, 1988 to May 27, 2009) and uses different methodology (GARCH models).

Tests of equality of two variances indicate a complexity of the phenomenon as significant differences between variances exist for almost all weekdays and months. It may imply that transaction risk can be affected both by the day of the week on which the deal is made and the month of the year. We believe our findings may be interesting for the actors in oil markets, including producers, refiners, financial institutions and individual traders.

References

Ball C., Torous W., Tschoegl A. [1982]: Gold and the Weekend Effect, *Journal of Futures Markets*, 2, 175-182.

Borowski K., Lukasik M. [2015]: Analysis of Selected Seasonality Effects in the Following Agricultural Markets: Corn, Wheat, Coffee, Cocoa, Sugar, Cotton and Soybeans. *Eurasian Journal of Business and Management*, 3 (2), 12-37.

Coutts J.A., Sheikh M.A. [2000]: The January Effect and Monthly Seasonality in the All Gold Index on the Johannesburg Stock Exchange 1987-1997. *Applied Economics Letters*, 7, 489-492.

Eller R., Sagerer Ch. [2008]: An Overview of Commodity Sectors. *The Handbook of Commodity Investing*, John Wiley&Sons, Hoboken, New Jersey, 681-711.

Geman H. [2007]: Commodities and Commodity Derivatives, John Wiley&Sons, Hoboken, Chichester, West Sussex.

Górska A., Krawiec M. [2014]: Analysis of Calendar Effects in Markets of Precious Metals. *Quantitative Methods in Economics,* 15 (2), 392-402.

Lee K., Hsu C., Ke M. [2013]: Testing the Monthly Effect of Agricultural Futures Markets. International Review of Accounting, Banking and Finance, 5, 35-60.

Lucey B.M., Tully E. [2006]: Seasonality, Risk and Return in Daily COMEX Gold and Silver Data 1982-2002. *Applied Financial Economics*, 16, 319-333.

Ma C. [1986]: A Further Investigation of the Day-of-the-Week Effect in the Gold Market. *Journal of Futures Markets*, 6 (3), 409-419.

Olowe R.A. [2010]: Oil Price Volatility, Global Financial Crisis and the Month-of-the-Year Effect. *International Journal of Business and Management*, 5 (11), 156-170.

Osińska M. [2006]: Ekonometria finansowa. PWE, Warszawa.

Schofield N.C. [2007]: Commodity Derivatives. John Wiley&Sons, Hoboken, Chichester, West Sussex.

Qi M., Wang W. [2013]: The Monthly Effects in Chinese Gold Market. *International Journal of Consumption Policy*, 34, 43-66.

Witkowska D., Matuszewska A., Kompa K. [2008]: Wprowadzenie do ekonometrii dynamicznej i finansowej. Wydawnictwo SGGW, Warszawa.

Yu H.C., Shih T.L. [2011]: Gold, Crude Oil And the Weekend Effect: a Probability Distribution Approach. *Investment Management and Financial Innovations*, 8 (2), 39-51.