WTI, the driver of the oil market in United States.

by

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A thesis submitted in conformity with the requirements
for the MSc in Economics, Finance and Computer Science

University of Huelva & International University of Andalusia

September/November 2017

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2017

Abstract

The oil market transcends beyond the barrel of crude oil. There are many derivatives obtained from this resource, therefore these can not be set aside when studying the evolution of the market. Likewise, natural gas is proposed in some investigations as a substitute for oil in the generation of energy. This paper studies the cointegration of these products in the market through 5 steps. First, we contrasted the existence of cointegration. In a second step we review the robustness of the first results and mathematically define this relationship by means of a vector model of error correction (VECM). In the last two steps we define the causality between variables, the transience of the shocks and the degree of dependence with respect to our main variable: WTI. The results confirm the existence of different degrees of cointegration between the derivative variables and allow a quantitative and qualitative specification of their intra-relations.

JEL classification: I25, I28, J24, J28, O52.

Key words: overqualification, job mismatch, self-employment, private paid employment, public paid employment, public intervention, EU-15.

Resumen

El mercado del petroleo va más allá del barril de crudo. Son muchos los derivados obtenidos de este recurso, por lo tanto, estos no pueden ser ignorados cuando analizamos la evolución del mercado. Asimismo, el gas natural es propuesto en algunas investigaciones como sustituto del petroleo en la generación de electricidad. Este trabajo estudia la cointegracion de estos productos con el mercado en 5 etapas. Primero contrastamos la existencia de cointegracion. Seguidamente revisamos la solidez de los primeros resultados y definimos matematicamente estas relaciones mediante un modelo vectorial de correccion del error (VECM). En los ultimos dos pasos definimos la casualidad entre variables, la trascendencia de shocks y el grado de dependencia respecto a nuestra variable principal: WTI. Los resultados confirman la existencia de diversos grados de cointegracion entre las variables de derivados y nos permite una especificacion cuantitativa y cualitativa de estas relaciones.

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1 Introduction

The oil market is clearly positioned as a main source of energy for the vast majority of economies. Within the oil market we have its derivates that are already processed for consumption as energy source (natural gas, gasoline, …). In the case of EE.UU, this dependence is strong, with fossil energies making up more than 70% of energy sources. Therefore, the repercussions of a negative shock on it dynamic are many. Hamilton (1983) and Mork (1989) showed how increases of oil prices are likely to cause recessions and consequently increase unemployment. But the scope of these disequilibrating shocks goes further affecting also to commodities prices clearly dependent on oil. These shocks can be grouped according to Kilian (2009) in three groups mainly: supply shock, demand shock and specific market shocks. Recently, Lin and Li (2015) add a new driver that they named “China factor”.

One of the major lines of research in this field is to study the cointegration among petroleum and natural gas product prices. The reason that leads us to study cointegration is that if this assumption is fulfilled, we can treat both variables as part of a new dynamic that relates them to each other. As a result, we can study different assumptions. In this paper we will begin by identifying the existence of cointegration among our variables. This is contrasted by Johansen's bi-variant tests. Then we perform the autoregressive error correction model (VECM) that allows us to see these cointegration relationships in much more detail through cointegration equations. To make sure of the existence of cointegration and also to give robustness to our statement, we will perform a test on β parameters obtained by VECM that retifies its unit expression. We continue defining the effect-cause relationship between our variables through the famous Granger causality test. As a final point to our research, we perform a Permanent-Trend contrast where those variables that react transiently to changes in dynamics will remain. This assumption is reinforced with impulse-response graphics and an analysis of the shared component between variables.

The central axis of the variables on which we will orbit the rest is the US oil market (WTI index). The reason is simple; three of our four remaining variables are direct derivatives of it (Gasoline, Diesel and Heating Oil). We also introduce a variable that gathers movements of the natural gas market in the United States (Henry Hub). The interest of introducing it is better defined late; we will see how its behavior moves away from the rest.

Therefore, the convergence between the importance of this topic and the recent methodology of applied study make this work a general review of the situation of the oil market in the USA through cointegration. In this way, the present research work can be used as an exemplary model of the methodology applied in cointegration transferable to other contexts or variables. With respect to the results, those presented here can be used to support other lines of research in the same context and even allow other researchers to take them as a basis for future research.

2 Selective review of previous literature

Since 1994, when Yucel and Guo find the existence of long-run link among crude oil and its refined products for the US with rigorous econometric techniques, there are many researches who confirm cointegration among oil-dependent energy markets for the US. Serletis and Herbert (1999) found common trends in Henry Hub and Transco Zone 6 natural gas prices, the New York Harbor fuel and PJM electricity prices. However, the Transco Zone 6 market does not move together with New York Harbor prices so they conclude that there must be regional competition between them. The same researcher with a new partner, Serletis and Rangel-Ruiz (2002), investigate the existence of common price cycles in US energy commodities using daily prices of Henry Hub and WTI. They find decoupling between both variables that they explain as a consequence of the deregulation that occurred in the year 2000. To complete in more detail the results offered by the previous research Villar and Joutz (2006) examine this apparent decoupling finding one cointegration relationship between the prices that exhibits a positive time trend, so they can conclude that the price of WTI is weakly exogenous to Henry Hub prices. Continuing with this research line, Asche et al. (2006) state a strong integration of oil and natural gas markets for the US. Brown and Yucel (2008) even show that both products can be considered as substitutes and also complements in the generation of electricity. But to take advantage of this substitution, it is clear that switching capacity is needed in electricity production plants, which is precisely why we only observed it in certain regions that have switchable infrastructures. Hartley, Medlock and Rosthal (2007).

Most of the researchers have used the ECM developed by Sargan (1964) identifying a long-run stochastic trend among oil market variables for US. Within this group we can highlight papers done by Balke et al. (1998), Griffin (2003), Chen et al. (2005), Brown and Yucel (2007) and

Honavar (2009). The latter indicates a possible technical error of ECM and VAR models. He identified misleading results when time series are not cointegrated but their positive and negative partial sums are cointegrated.

One of the main problems estimating by ECM is the appearance of sporadic imbalances. These may be due to the occurrence of shocks discussed above. Hartley et al. (2008) demonstrate that the short-run dynamic is affected by a couple of exogenous variables named by him as inventories, weather and other seasonal factors. Brown and Yucel (2007) also find deviations in the short-run relationship regarding the long-run one that they named "market fundamentals" (weather, store levels …). To contemplate this problem when modeling, some investigators like Hartley, Medlock and Rosthal (2007) includes some stationary exogenous variables in their VECM to identify departures from the relationship. Others like Lin and Li (2015) identify indirect effects by studying price and volatily spillovers between oil and natural gas markets.

Other interesting research to review for using novel or different technique is the quantile autoregressive distributed lags model (QARDL) developed by Lahiani, A., Miloudi, A., Benkraiem, R., & Shahbaz, M. (2017). that help us to contemplate the short-run and long-run relationship distributed by quantiles. The results achieved in this paper demonstrate a linear and symmetric long-run relationship across quantiles and a significant short-run relationship between natural gas and oil prices mainly in medium and high quantiles. Meanwhile Brigida (2014) employs a multi-state Markov Switching model to investigate the cointegration between oil and natural gas prices. A remarkable results of her investigation indicates that both variables did not decoupled in the early 2000 as Serletis and Rangel-Ruiz (2002)inferred from their results but rather experienced a temporary shift in regimes.

Althought the existence of prices cointegration is evident; the mechanism of price transmission may show asymmetries. Borenstein et al. (1997) confirmed that retail gasoline prices respond more quickly to increases than to decreases in crude oil prices . Regarding this matter, we find diverse and conflicting positions between the investigators. While Bachmeier and Griffin (2003) find no evidence of asymmetry in the response of gasoline prices, Balke et al. (1998) had previously detected asymmetry over the same period of time. Despite the fact that other researchers such as Vendetti (2010) are located next to Bachmeier and Griffin hypothesis, this divergences may be explained by the use of different temporal frequencies because the vast majority of empirical studies advocate the existence of asymmetry in US energy markets (see Frey and Manera, 2007 for an extensive review of this literature). In more recent studies, Atil et al. (2014) find that gasoline and natural gas prices respond differently to changes in oil prices so they can say that theirs transmission mechanism are different. In line with this last statement and with the intention of better defining this phenomenon Aloui et al. (2014) apply the copula-GARCH methodology finding that this asymmetry between oil and natural gas markets occurs during bullish periods and not during bearish periods.

To finish this review of the literature, consider investigations carried out at a higher aggregation level. As we pointed out in the introduction, the oil market functions as the main energy supplier of the economies, not only US economy. Consequently, its strongly and globalized character is not surprising. In fact, research carried out in the last decade showed this global cointegration. Bachmeier and Griffin (2006) find evidence of cointegration across various commodity markets. In the case of crude oils markets they find them strongly cointegrated. Moreover, they point out that the global market can be considered as a single primary energy market in the long term. Other research that supports this assumption starting from the EE.UU case is the one made by Serletis and Rangel-Ruiz (2002). They show that the cointegration among US energy prices indices is also replicated with the Canadian natural gas indices (AECO). In the same way but for the UK case, Asche, Osmundsen and Sandsmark (2006) reports the existence of a single market for primary energy in the UK in which prices are affected exogenously by the global market. Lin and Li (2015) also come to similar conclusions. In their paper the find that European and Japanese gas markets are cointegrated with US Brent.

3 Data and Econometric specification

3.1 Data

The dataset includes weekly US time series of prices for WTI crude oil, gasoline, diesel, heating and Henry Hub. We have downloaded these series from the website of the U.S. Energy Information Administration (EIA). Times series covers the period from the week of January 10, 1997 to the week of October 6, 2017. This interval comprises 1075 weekly observations. All prices are expressed in dollars. WTI are the initials of West Texas Index that picks up most of the national oil market. The Henry Hub variable collects data recorded by the national natural gas distribution center (with the same name) located in the state of Louisiana. Heating oil is a low viscosity, liquid petroleum product used as a fuel oil for furnaces or boilers in buildings. Home heating oil is often abbreviated as HHO. Gasoline and Diesel most prolific uses are as fuel for various products such as automobiles, heavy machinery, generators and many other common appliances.

Table 1 shows the main statistics that help us to get a global idea of the properties of each variable. As we can see, all the variables show a positive skewness and kurtosis excess so the tails of their distributions are coarser than the normal distribution.

Table 1. Descriptive statistics

	WTI	Gasoline	Heating	Diesel	Hernry Hub
Mean	55.635	1.589	1.606	1.722	4.427
Std. Dev.	29.940	0.836	0.902	0.904	2.265
Min	11	0.296	0.29	0.379	1.34
Max	142.52	3.363	3.992	4.057	14.49
Skewness	0.418	0.330	0.436	0.384	1.47
Kurtosis	2.068	1.897	2.046	2.006	5.62

3.2 Econometric specification

Engle and Granger (1987) demonstrate that if two variables are cointegrated, then there must exist a model based on error correction of the dynamic system governing the joint behavior of both variables. That means that there is a long-run equilibrium relationship between the variables then we can make statistical inference.

To verify the existence of cointegration relationships we estimate Johansen's test for cointegration (1995). As we have 1075 observations, problems related with limited samples when applying this test are overcome.

Starting from a VAR representation of our model as follows:

$$x_t = v + A_k x_{t-1} + \varepsilon_t \tag{1}$$

Lags orden selection is based on AIC criteria. Once we get it we transform this VAR representation into a vector error correction model (VECM) by using the difference operator $\Delta=1-L$, or $L=1-\Delta$. Obviously, we lost one k-period in the differentiation.

$$\Delta x_t = v + \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1} \Delta x_{t-k-1} + \Pi x_{t-1} + \varepsilon_t \tag{2}$$

Generalizing the last model we get:

$$\Delta x_t = v + \sum_{i=1}^{k-1} \Gamma_1 \ \Delta x_{t-I} + \Pi x_{t-1} + \varepsilon t \tag{3}$$

Where Γi's and Π are matrixes of variables.

The rank of Π matrix determines the number of independent rows in Π and consequently the number of cointegration vectors. The number of cointegration vectors means the number of stationary relationship so each significant eigenvalue represent a stationary relation.

From Eq(3), we can obtain the following results after applying the test:

- If rank $\Pi=0$ all variables are non-stationary.

- If rank $\Pi=\rho$, so Π has a full rank, then all variables must be stationary.

- If Π has reduced rank, $0 < r < p$, there are some cointegration relations among the variables. The cointegrating vectors are given as $\Pi=\alpha\beta'$ where βi represents the *i*-th cointegration vectors, and αj represents the effect of each cointegrating vector on the $\Delta x_{p,t}$ variables in the model.

Johansen derived two test, the λ−max (or maximum eigenvalue) and the λ−trace (or trace test). Some investigations Reimerers (1992) demonstrate that the trace test is better test because it appears to be more robust to skewness and excess kurtosis. Most of statistical programs include both and also agree in their affirmation so we present both in the table 7.

Then, according to the existing literature, cointegration implies a VECM such as:

$$\binom{\Delta wti}{\Delta deriv} = \binom{\alpha_{wti}}{\alpha_{deriv}} (wti_{t-1} - \beta deriv_{t-1} - c) + \sum_{i=1}^{n} \Gamma_i \binom{\Delta wti_{t-i}}{\Delta deriv_{t-i}} + \binom{w_{1t}}{w_{2t}} \tag{4}$$

Where "α" are adjustment parameters. The coefficient of cointegration is "β". Restricted constant is "c", lag length "n" and errors are "w". The Γ_i parameters are (2x2) matrices that compile the short-run dynamics. Speed of adjustment is captured in α_{wti} and α_{deriv}. The "deriv" index refers to our oil derivates variables (gasoline, diesel and heating).

Having proof of the existence of cointegration and having obtained β and α parameters through VECM, we will proceed to perform a Granger causality test (1969). The null hypothesis is that lagged X-values do not explain the variation in y. In other words, it assumes that X(t) doesn't Granger-cause y(t).

To complete this statistical work with data that detail closely the dynamics of the relationship of the alleged cointegration relationship, we will study the Permanent-Transitory decomposition. Following Gonzalo and Granger (1995) Permanent-Transitory decomposition, we can decomposed X_t into a transitory (or stationary) part $\beta' X_t$ and a permanent part $W_t = \alpha' X_t$. The last parameter, Wt, is the common permanent component of X_t so it is interpreted as the dominant variable.

One interpretation of α coefficient is as a measure of the imbalance of errors generated by changes in X_t. That means that if α=0, the variable is weakly exogenous, or what is the same, the variable does not react to the imbalance of errors, i.e. the transitory component, implying that the variable is the main contributor to the common trend.

In order to determine this proportion we estimate the Component Share (CS). This statistic relates in a simple way "α" of both variables to define which variable behaves as "driver" in the cointegration relation.

$$CS_1 = \frac{\alpha_2}{\alpha_2 - \alpha_1}, CS_2 = \frac{-\alpha_1}{\alpha_2 - \alpha_1} \tag{5}$$

Once we have detailed the methodology that we are going to follow to define the relations of cointegration between our variables and before going on to comment the results, we think it is a good idea to make a scheme that includes all the steps expressed, thus facilitating the reader a global vision of the exercise showed in table 2.

Table 2. Procedure script.

	Procedure	Hypotheses
Step 1	Is there cointegration between variables?	H_1: (r = 1) One cointegration relationship
Step 2	Estimation of β	H_1^{β}: Cointegrating vector is (1,-1)
Step 3	Estimation of adjustment coefficients	$H_1^{\beta} \cap H_1^{\alpha i}$: Variables are weakly exogenous under the restriction of the cointegrating vector (1,-1)
Step 4	Granger causality test	H_1^{G}: wti-derivatives causality relationships
Step 5	Permanent-Transitory decomposition	$H_1^{\beta} \cap H_1^{\alpha_{wti/deriv}} \equiv H_1^{\beta} \cap H_1^{\alpha_{deriv/wti}}$: Variables has a permanent component in the common trend.

4 Results

Starting from the assumption of non-stationarity for our series (unit root analysis in table 9.), the cointegration test applied to the variables (table 3.) shows that cointegration exists in all the variables except Henry Hub. The special behavior of this variable could be due to the deregulation of natural gas that occurred during the beginning of the 21st century as Serletis & Rangel-Ruiz (2002) supports in his work.

Table 3. Lag length selection and bivariate Johansen's cointegration tests.

								Log_WTI/log_GASOLINE
Lags	1	2	3	4	5	6	7	8
AIC	-7.250	-7.283	-7.295	-7.304	**-7.306**	-7.303	-7.303	-7.299

Rank	Log-Likelihood	λ	$Lambda_{max}$	Lambda 0.95	Trace	Trace 0.95
0	3938.960	-	40.591	15.67	43.357	19.96
1	3959.256	0.036	2.766	9.24	2.766	9.42

								Log_WTI/log_DIESEL
Lags	1	2	3	4	5	6	7	8
AIC	-7.251	-7.364	-7.394	-7.396	-7.398	-7.399	**-7.414**	-7.413

Rank	Log-Likelihood	λ	$Lambda_{max}$	Lambda 0.95	Trace	Trace 0.95
0	4001.240	-	31.958	15.67	35.000	19.96
1	4017.220	0.029	3.041	9.24	3.041	9.42

								Log_WTI/log_HEATING
Lags	1	2	3	4	5	6	7	8
AIC	-7.645	-7.737	-7.796	-7.804	-7.807	-7.814	-7.815	**-7.819**

Rank	Log-Likelihood	λ	$Lambda_{max}$	Lambda 0.95	Trace	Trace 0.95
0	4217.027	-	36.257	15.67	36.649	19.96
1	4235.156	0.033	3.391	9.24	3.391	9.42

								Log_WTI/log_HENRYHUB
Lags	1	2	3	4	5	6	7	8
AIC	-5.881	-5.919	-5.920	-5.930	-5.932	-5.932	**-5.933**	-5.930

Rank	Log-Likelihood	λ	$Lambda_{max}$	Lambda 0.95	Trace	Trace 0.95
0	3216.843	-	7.032	15.67	10.043	19.96
1	3220.359	0.006	3.010	9.24	3.010	9.42

After this step, we will continue our process scheme discarding Henry Hub variable. By developing the VECM model on the three remaining variables in which there is cointegration, we obtain the results shown in table 4. For the three remaining variables we have existence of cointegration. In addition, both the cointegration coefficients β and the adjustment parameters α are statistically significant for these three variables which contain petroleum derivatives. We verify that β's are very close to the unit for all cases (they are negative due to their transfer in the equation at the time of calculation).

Table 4. VECM Long-run parameters.

		Log_WTI/Log_GASOLINE
	β	α
Log_WTI	1.000 (0.000)	-0.0158
Log_GASOLINE	-1.023 (0.023)	0.0636
Constante	-3.542 (0.015)	
		Log_WTI/Log_HEATING
	β	α
Log_WTI	1.000 (0.000)	-0.00711
Log_HEATING	-0.939 (0.017)	0.071439
Constante	-3.575 (0.012)	
		Log_WTI/Log_DIESEL
	β	α
Log_WTI	1.000 (0.000)	-0.0090037
Log_DIESEL	-1.033 (0.023)	0.069896
Constante	-3.450 (0.016)	

Note: P-values in brackets.

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However, as we indicated in the introduction we are going to make a new contrast H_1^β that confirms that β is close to the unit and therefore does not generate distortions in the relationship. The results of this contrast (showed in table 5.) confirm that β is equal to 1 in all cases except Heating. Therefore, we can affirm that there is a "one-to-one" relationship between the variables evidencing cointegration.

Table 5. Cointegrating vector test.

H_1^β	Gasoline	Heating	Diesel
β = (1, -1)	0.900 (0.343)	8.548 (0.003)	1.889 (0.169)

Note: P-values in bracket.

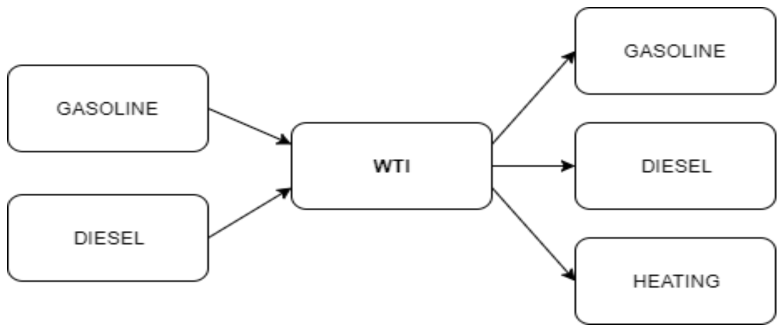
In spite of this, this relationship of cointegration does not always occur in both directions. Continuing with the Granger causality test, the results show the existence of causality between all the variables at a minimum confidence level of 90% except for variable "Heating". Causality contrast result in table 6. Relationships are expressed graphically in figure 1.

Table 6. Granger causality contrast.

Derivatives	WTI → Derivatives	Derivatives → WTI
Gasoline	12.435 (0.014)	20.354 (0.000)
Heating	13.036 (0.071)	9.633 (0.210)
Diesel	23.189 (0.007)	13.920 (0.030)

Note: P-values in bracket.

Figure 1. Granger-causality map.



Through a contrast of nullity applied to the "$\hat{\alpha}$" adjustment component, we can check whether the variable corrects its evolution to return to the equilibrium relation or if on the contrary it remains indifferent to changes on the other cointegrated variable, thus taking a position of "driver" in the cointegration relation. The results of this contrast are given in table 7. In this last contrast we have discarded the variable "Heating" that in the previous step was shown to be absent of causality over WTI. For our two remaining variables the variable WTI is positioned as leader of the relationship with very similar statistical results. These results are calculated following the methodology proposed by Gonzalo & Granger (1995) that decomposes variables into permanent and transitory components.

Table 7. Gonzalo & Granger Permanent-Trend test

	α_{DIESEL}	α_{WTI}	$\alpha_{GASOLINE}$	α_{WTI}
LR Stadistic	0.062***	-0.016	0.061***	-0.014
	(0.017)	(0.016)	(0.016)	(0.015)

Note: P-values in bracket.

To finish with the research work we have investigated a little more in the existing causality relationship. For this we have calculated the Shared Component that reflects the proportion or the weight of each variable on WTI and vice versa. These proportions are calculated in percentage terms and show that for both variables there is a very similar relationship with WTI. We can see the results in table 8. At this point we can confirm that the Diesel and Gasoline variables follow the WTI stochastic trend and that they do so in a very parallel way.

Table 8. Component Share results.

GASOLINE		DIESEL	
CS_{WTI} = 79.49%	$CS_{GASOLINE}$ = 20.51%	CS_{WTI} = 76.25%	CS_{DIESEL} = 23.75%

5 Conclusions and avenues for further research

There are many interesting conclusions we can draw from these results. For greater understanding, review them according to the sequential order that we have followed at work. The first major conclusion we extract supports an extensive literature Serletis & Herbert (1999), Asche et al. (2006) that identifies divergences between the variables related to oil and our natural gas variable Henry Hub. As we already mentioned this decoupling is probably due to the national deregulation of the natural gas market that since the beginning of this century has been gaining importance. Consequently, new agents have entered in these markets destabilizing the existing relationship of cointegration in these primary energy markets, Serletis & Rangel-Ruiz (2002). We thus confirm the non-existence of substitutability between natural gas and oil markets in the generation of energy, as pointed out by Brown & Yucel (2008).

With the results obtained after the cointegration and causality tests we can marginalize the variable Heating from the rest. The great similarity of these two variables is also visible in the impulse-response graphics (Figure 1.) where both react positively and very parallel to a shock in their trajectory while Heating would react differently. We check again how this variable maintains a different relationship with WTI. The fact that Heating does not cause WTI but is caused by it can be interpreted according to the following statements. This difference with respect to our two variables may be due to the difference in their use. Also the seasonal nature of the use of heating systems that grow more in the colder months of the year causes this series to present a different trajectory.

Finally, we see how Gasoline and Diesel are the two most cointegrated variables with WTI. We think this strong relationship is because both resources are destined to highly similar consumptions (mainly in machinery). It is suggested that WTI price movements will affect the movements of these fuels in a 7:10 ratio. In a complementary way, the movements in the market of these fuels will affect in an approximated 3:10 proportion to the WTI. The greater weight of WTI in the relationship is due to the fact that oil is the resource to be refined in the obtaining of these fuels in question.

Arriving at this final point we suggest various ideas for the development of this role arising from the study of conclusions. A first idea would be to continue the analysis of the relationship between WTI and Diesel or Gasoline. Said variables taken as a ratio in relation to WTI can be taken as the error. The existence of β persistently equal to the unit allows us to clear the error and put it in function of this ratio. We can even relate this ratio with the Gallons / Barrel ratio that by convention is fixed and that shows divergences with the real market prices. Another way of research could relate these results to the Brent index. Through this last one we could see how both markets compete. But we can also go back a few steps and better define the relationship between oil and natural gas. In short, this paper leaves many lines of research open, as it contains results of great use.

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Appendix

Table 9. ADF Unit-Root test.

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
LogWTI	-1.856	-3.430	-2.860	-2.570
			MacKinnon approximate p-value for Z(t) = 0.35	
LogGASOLINE	-1.932	-3.430	-2.860	-2.570
			MacKinnon approximate p-value for Z(t) =0.31	
LogHEATING	-1.656	-3.430	-2.860	-2.570
			MacKinnon approximate p-value for Z(t) =0.45	
LogDIESEL	-1.614	-3.430	-2.860	-2.570
			MacKinnon approximate p-value for Z(t) =0.47	
LogHENRY HUB	-2.520	-3.430	-2.860	-2.570
			MacKinnon approximate p-value for Z(t) = 0.11	

Table 10. WTI-GASOLINE VECM

	ΔlogWTI	ΔlogGASOLINE
α_{wti}	-0.015	-
α_{gas}	-	0.063***
Γ_{t-1}^{gas}	0.067*	0.122***
Γ_{t-2}^{gas}	0.105***	0.055
Γ_{t-3}^{gas}	0.090**	0.088**
Γ_{t-4}^{gas}	-0.048	0.028
Γ_{t-1}^{wti}	0.125***	0.104**
Γ_{t-2}^{wti}	-0.182***	-0.105**
Γ_{t-3}^{wti}	0.036	0.044
Γ_{t-4}^{wti}	-0.013	-0.082*

Table 11. WTI-HEATING VECM

	ΔlogWTI	ΔlogHEATING
α_{wti}	-0.007	-
α_{hea}	-	-0.071***
Γ_{t-1}^{hea}	0.046	0.286***
Γ_{t-2}^{hea}	0.054	-0.157***
Γ_{t-3}^{hea}	0.024	-0.039
Γ_{t-4}^{hea}	-0.028	0.019
Γ_{t-5}^{hea}	0.075	-0.035
Γ_{t-6}^{hea}	0.077*	0.045
Γ_{t-7}^{hea}	0.001	-0.100
Γ_{t-1}^{wti}	0.155***	0.043
Γ_{t-2}^{wti}	-0.154***	-0.031
Γ_{t-3}^{wti}	0.101**	0.088*
Γ_{t-4}^{wti}	-0.039	-0.107**
Γ_{t-5}^{wti}	0.029	0.075
Γ_{t-6}^{wti}	-0.123***	-0.068
Γ_{t-7}^{wti}	0.001	0.061

Table 12. WTI-DIESEL VECM

	ΔlogWTI	ΔlogDIESEL
α_{wti}	-0.009	-
α_{die}	-	0.069***
Γ_{t-1}^{die}	0.070*	0.304***
Γ_{t-2}^{die}	0.096**	-0.067*
Γ_{t-3}^{die}	0.001	-0.044
Γ_{t-4}^{die}	-0.025	0.011
Γ_{t-5}^{die}	0.025	-0.066*
Γ_{t-6}^{die}	0.345	-0.102***
Γ_{t-1}^{wti}	0.144***	0.067*
Γ_{t-2}^{wti}	-0.174***	-0.097**
Γ_{t-3}^{wti}	0.119***	0.126***
Γ_{t-4}^{wti}	-0.043	-0.021
Γ_{t-5}^{wti}	0.061	0.108***
Γ_{t-6}^{wti}	-0.089**	0.039

Table 13. WTI-HENRYHUB VECM

	ΔlogWTI	ΔlogHENRYHUB
α_{wti}	-9.07e-05	-
α_{hh}	-	0.004***
Γ_{t-1}^{hh}	0.017	0.123
Γ_{t-2}^{hh}	0.006	-0.025
Γ_{t-3}^{hh}	-0.020	-0.058*
Γ_{t-4}^{hh}	0.035*	-0.036
Γ_{t-5}^{hh}	-0.009	-0.050*
Γ_{t-6}^{hh}	-0.009	-0.007
Γ_{t-1}^{wti}	0.188***	0.116**
Γ_{t-2}^{wti}	-0.113***	-0.042
Γ_{t-3}^{wti}	0.129***	-0.019
Γ_{t-4}^{wti}	-0.061**	-0.044
Γ_{t-5}^{wti}	0.075**	-0.025
Γ_{t-6}^{wti}	-0.055*	0.110

Figure 1. Impulse response graphs