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Short-and Long-Term Relations among Prices of the Mexican Crude Oil Blend, West Texas Intermediate, and Brent: Market Trend and Risk Premia, 2005-2016

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ABSTRACT

This paper uses a vector error correction model to obtain the decomposition in permanent and transient components of prices of the Mexican Crude Oil Blend, the west Texas intermediate oil, and the Brent oil of the North Sea. Moreover, Granger causality tests, impulse-response analysis, and variance decomposition are carried out. The main findings are: (1) There are long-term relationships among these oil prices, (2) Brent oil mainly sets the market trend for the Mexican Crude Oil Blend, and (3) the yield-risk analysis shows that the Mexican crude oil blend offers the highest average yield and Brent provides the highest average risk premium.

Keywords: Oil Prices, Econometric Modeling, Yield-risk Analysis
JEL Classifications: Q41, C51, G83

1. INTRODUCTION

The global economic and financial environment has changed dramatically during the last two decades with consequences difficult to predict. Along with this, oil prices, reflecting the weight of oil producing countries and the impact of climatic factors, suffered unexpected and sudden fluctuations increasing the uncertainty of economic activity of most countries. Another additional factor that has impacted oil prices is the depletion of oil, which has led to resource substitution in multiple end-use sectors (Lubna and Ajith, 2013).

Mexico, as an oil producing country, during 2013 exported an oil barrel exceeding 100 USD on the average. However, at the beginning of 2016, it dropped below 30 USD, which brought a significant decrease in its purchasing power and an increase in its indebtedness. It also reduced its fiscal income and caused liquidity problems in its oil company, PEMEX (acronym for Petróleos Mexicanos), affecting the investment programs necessary for the development of the industry; while the fall in oil prices produced a major stimulus for the importing countries.

The oil industry in Mexico is among the largest in the world and the thirteenth largest in crude oil exports. Mexico is also among the countries with the largest oil reserves, and it is worthwhile mentioning that is not a member of the OPEC. The Mexican oil sector is crucial for the expansion of the economy since revenues collected by the government from exporting crude oil represent around 35% of total government income. The market value of Mexican crude oil exports (MCE) depends essentially on two factors: (1) The crude performance in the refining process to obtain derivative as butane, propane, gasoline, kerosene, etc.; and (2) the energy needed in the refineries to remove the sulfur content in the crude oil in order to meet the quality specifications in the finished products. These two factors of density and sulfur content define the desirability of the Mexican crude oil and, thus, the price to be paid for it. It is important to recognize that in Mexico petroleum is first traded as a raw material for refineries, and secondly as a finished product.

The Brent oil, the light North Sea crude oil, and the west Texas intermediate (WTI) oil, a lighter crude oil, produced in Texas and Oklahoma in the USA, are both used as reference for pricing the

MCE, which are composed, mainly by three oils: Mayan, Istmo and Olmeca oils. Consequently, the price of Mexico's crude oil has shown a trend parallel to that observed by the reference crude oils WTI and Brent. The objective of this paper is to examine the short-and long-term relationships among prices of the MCE, WTI and BRENT crude oils. Specifically, the econometric analysis is carried out through the methodology from Gonzalo (1994), Gonzalo and Granger (1995) and Gonzalo and Pitarkis (1998) that propose a test to estimate common long-memory components in cointegrated systems and a model selection approach for the specification of the cointegrating rank in the vector error correction model (VECM) representation of vector autoregressive models[1].

This research is organized in the following way: Section 2, briefly, introduces the econometric methodology that will be used in this paper; Section 3 carries out an econometric analysis through a VECM; finally, conclusions of the study are presented.

2. ECONOMETRIC METHODOLOGY

Since the appearance of Granger (1981) and Engle and Granger (1987) models, the analysis of cointegration has been extensively used. The absence of cointegration implies that there are no common trends among the observed values of the analyzed variables. Several methods have been developed to examine long-term relationships between non-stationary time series. As the degree of integration among oil markets increases, there is also an augment in the speed and intensity with which short-term events are transmitted between these markets. The transmission of related events in the short term produces, in turn, that in the long term there are common trends in the behavior of crude oil in an integrated way. In this regard, Gonzalo and Granger (1995) verify the dominance assumption among crude oil that is fed mainly by variations in the short term in which a time series X_t is broken up in a permanent component, P_t, and a transitory component, T_t, in such a way that:

$$X_t = P_t + T_t \quad (1)$$

If there is a long-run equilibrium, it will be determined by permanent elements, P_t, thus, the transient component, T_t, represents long-term equilibrium deviations. Under the hypothesis of existence of r vectors of cointegration the parameter matrix, Π, can be decomposed into a product of two matrices $\gamma_{n\times r}$ and α of order n×r, that is,

$$\Pi = \gamma_{n\times r}\alpha' \quad (3)$$

The matrix $\gamma_{n\times r}$ contains the correction parameters known as the adjustment coefficient and represents the weight of each of the cointegration vectors in the system equation.

$$X_t = P_t + T_t = \alpha_\perp\left(\gamma'_\perp\alpha_\perp\right)^{-1}\left[\gamma_\perp X_t\right] + \gamma\left(\alpha'\gamma\right)^{-1}\left[\alpha' X_t\right] \quad (4)$$

Where the matrix $\alpha_{n\times r}$ is the vector of cointegration such that $\alpha' X_t$ is stationary I(0) with $r \leq n$ and $\gamma_\perp X_t$ is the common factor that gives rise to the permanent component. The matrices $\alpha_\perp$ and $\gamma_\perp$ refer to the orthogonal component of α and γ, respectively. The estimation of the common factor is simpler by means of the decomposition of Gonzalo and Granger (1995) expressing that:

$$X_t = A_1 p_t + A_2 Z_t \quad (5)$$

Where,

$A_1 = \alpha_\perp\left(\gamma'_\perp\alpha_\perp\right)^{-1}$, $A_2 = \gamma(\alpha'\gamma)^{-1}$, and $z_t = [\alpha' X_t]$. In this case, $f_t = [\gamma_\perp X_t]$ is the common factor. Therefore,

$$X_t = A_1\gamma' X_t + A_2\alpha' X_t \quad (6)$$

3. DATA AND EMPIRICAL RESULTS

This research uses monthly prices of the MCE Mix, the WTI and the BRENT in the period 2005-2016. The data were obtained from the National Hydrocarbons Commission of Mexico. Figure 1 shows the dynamics of oil prices from 2005 to 2016 on a monthly basis, showing all the time series the same trend in the whole period analyzed, although Brent is the one with the greatest stability in comparison with others. After performing the analysis of the average logarithmic yields of the 3 crude oils for the period 2005-2016, it is found that the WTI yield is 0.08%, BRENT is 0.14%, and MCE is 0.28%, which shows that the oil that offers the highest yield is the MCE.

For the case of the risk market analysis represented by the variance on the yields, Var_{R1}, the WTI presents a risk rate of 9.2%, BRENT of 8.91%, and MCE of 9.35 % the crude oil market that offers lower risk is BRENT[2], although it outperforms the WTI. Under this framework, the Mexican crude is a dominant and attractive index to invest. With respect to the risk premium[3](RP) over the returns and the associated risks, the results are that the WTI has a RP of 0.0706, BRENT has a RP of 0.1466 and MCE has a RP of 0.287, in this sense BRENT has the highest RP.

On the other hand, Figure 2 shows the yields of MCE, Brent and WTI crude oils are highly volatile during 2008-2016, which forces us to carry out a more detailed analysis several econometric tests such as the unit roots and the Johansen cointegration will be applied by using Eviews 9.0.

3.1. Unit Roots Analysis

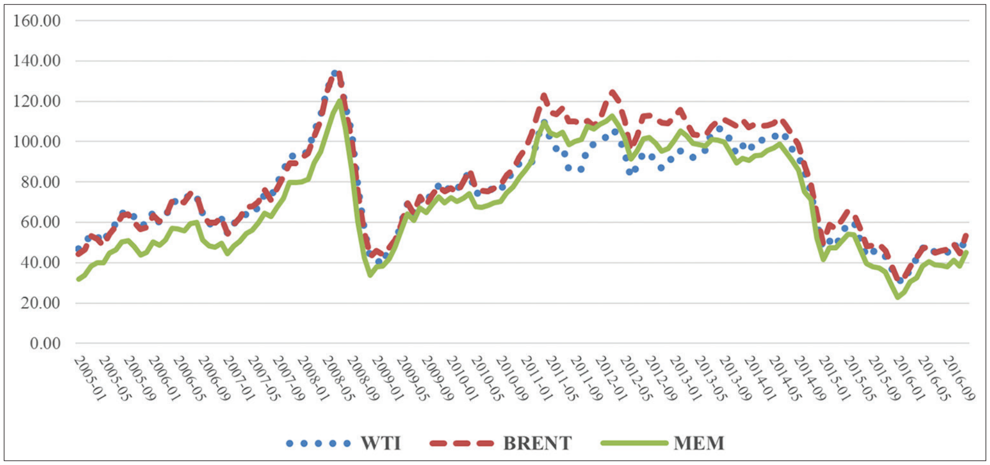
In what follows, the Augmented Dickey-Fuller test is applied to determine the degree of integration of the analyzed time series. The results show that at a 95% level of significance, it is possible to

1 See also Figuerola and Gonzalo (2008) and Harris et al. (1997; 2002). Other studies that apply time series models to study oil prices dynamics are: Ozturk and Arisoy (1999) and Uddin et al. (2014), Pavithra (2017), Nirmala and Swarna (2017), Lee and Chiu (2011), Erb and Harvey (2006), Fattouh (2010), Jiménez-Preciado et al. (2017), and Santillán-Salgado and Venegas-Martínez (2016).

2 See also Melolinna (2011) that studies the risk premia in future prices of crude oil with a Bayesian Autoregressive Vector Model (B-VAR).

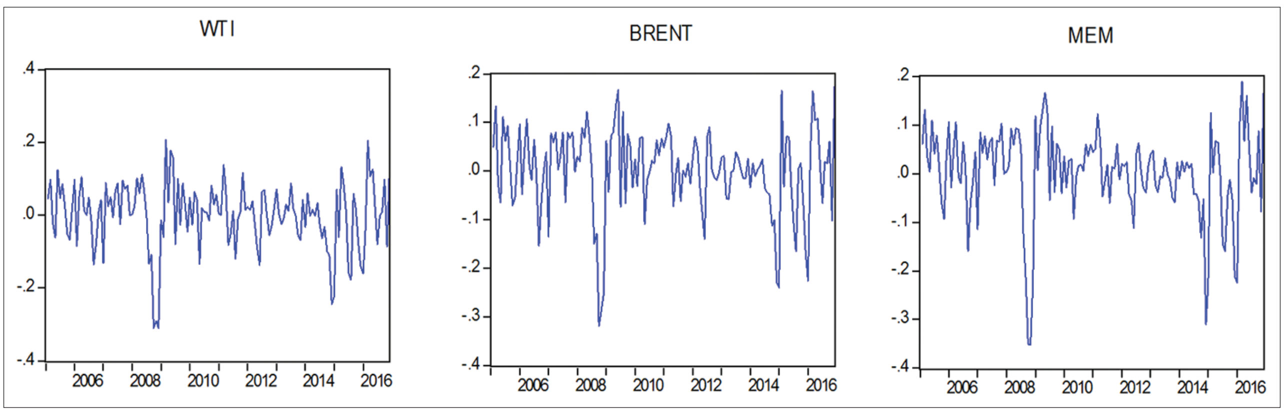
3 PR = (R1−TLP)/VarR1; Where PR is the risk premium; R1 is the logarithmic yield; TLP it is the risk-free rate (from t-bills); VarR1 is the variance of the logarithm yields.

Figure 1: Prices of Mexican crude oil exports, BRENT, and west Texas intermediate from 2005 to 2016 (Dollars per barrel)



Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico

Figure 2: Monthly yields of Brent, Mexican crude oil exports, and west Texas intermediate from 2005 to 2016



Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico

state that the MCE, BRENT and WTI are not stationary variables in levels, but they are in first differences as shown in Table 1.

3.2. Johansen Cointegration

It is now important to establish the relationship of cointegration. To do this, Johansen's methodology includes the tests of the trace and λ−Max. The model used to perform this test on the sample of the first period considers a lag based on the criterion of Schwarz. The trace test indicates that the null hypothesis (H_0:r=0) is validated, and since the value of the trace is greater than the critical value, thus the alternative hypothesis is rejected (Table 2).

After applying Johansen and Juselius' (1990) test, the results are favorable. On the one hand, the statistic of the trace is greater than the critical values of 5% level of significance, so the null hypothesis of the existence of cointegrating vectors is rejected. On the other hand, the test of the maximum eigenvalue is confirmed. Therefore, there is more than one vector of cointegration. According to the Johansen test, the MCE, BRENT and WTI maintain a long-term relationship.

To identify the common factor vector $\gamma_{\perp}$ for this case, a simple implementation of the orthogonality condition $\gamma'_{\perp}\gamma=0$ implies that $\gamma'_{\perp}=[1,0,0]$. That is, the price P_{WTI} is 100% responsible for fixing the trend. The calculations done with this methodology show that the common factor among these crude oils is the price of BRENT with a very short difference and it is the one that sets the trend in the long term, although in the short term it does not:

$$f_t = [\gamma_{\perp}X_t] \text{ and } f_t=P_{BRENT} \qquad (7)$$

3.3. Granger Causality Tests

The causality test in the sense of Granger seeks to determine statistically if the past of a variable contains information that precedes the behavior of another variable or *vice versa*; being very sensitive to the number of lags. The Granger causality test for the studied time series is presented in Table 3 and it shows that WTI and BRENT causes MCE in the sense of Granger, but the latter does not cause WTI and BRENT.

3.4. Impulse-Response Analysis

Impulse-response analysis is a useful tool to evaluate the congruence and dynamic sensitivity of the variables specified in a model, assuming that there are no covariances. That is, the errors have to be uncorrelated, otherwise it would be impossible to specify the response of a variable to impulses of other specific variables.

The following analysis generates three cases (all variables against all) in an interval time of 10 moths. This is done in order to examine the process of changes and adjustment in a complete way. Figure 3, Panels A, D and G show the response of MCE and WTI to impulses of the BRENT. It is observed that it starts positive during the 1st 9 months, then the impact decreases and it reaches stability in the tenth period. Panels B, E and H show the response of the BRENT and WTI to impulses of the MCE. In this case, it is observed that it starts positive during the 1st 8 months. Subsequently, the impact decreases and reaches stability in the ninth period. Finally Panels C, F and I show the response of the BRENT and MCE to impulses of the WTI, it is observed that it begins with negative shocks during the 1st 4 months, and the impact decreases reaching stability in the sixth period.

Table 1: Augmented Dickey Fuller test

Order of integration	Variable	Intercept	Trend and intercept	None
I(0)	MCE	0.0795	0.2659	0.6678
I(1)	ΔMCE	0.0000	0.0000	0.0000
I(0)	BRENT	0.1249	0.3587	0.6614
I(1)	ΔBRENT	0.0000	0.0000	0.0000
I(0)	WTI	0.4672	0.4178	0.3026
I(1)	ΔWTI	0.0001	0.0006	0.0000

Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico. MCE: Mexican crude oil exports, WTI: West Texas intermediate

Table 2: Cointegration test of the crude oils

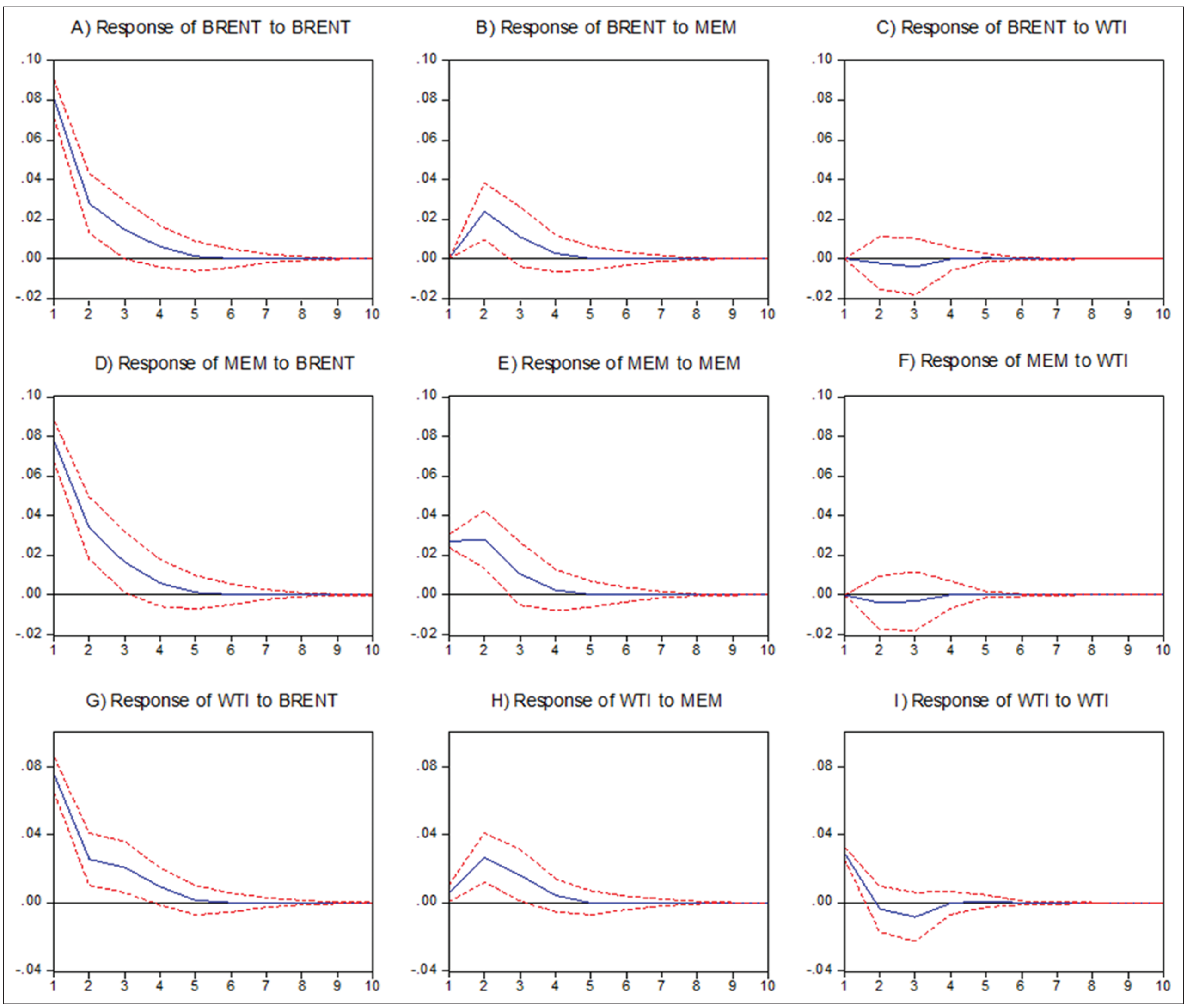
2005-2016	Trace		λ−Max	
None	167.3036	29.79707	80.38826	21.13162
No more than 1	86.91534	15.49471	55.00036	14.26460
No more than 2	31.91498	3.841466	31.91498	3.841466

Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico

3.5. Variance Decomposition Analysis

A complementary study to the impulse-response analysis is the decomposition of the variance with which the percentage of volatility recorded by one variable is reported in the different horizons due to the shocks of the others. In this way, it is possible to measure the volatility generated by the endogenous variable to the exogenous variable at a specific moment. Table 4 summarizes the results for the first, fifth and tenth periods. It is observed that the variable that has a strong autoregressive behavior is the BRENT price because after 10 months more than 91% is still explaining by

Figure 3: Impulse-response analysis



Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico

Table 3: Granger causality test results

Lags	Null hypothesis	χ^2	P
3	MCE does not cause BRENT	12.03861	0.0024
	MCE does not cause WTI	16.49596	0.0003
3	BRENT does not cause MCE	2.253775	0.3240
	BRENT does not no cause WTI	2.847817	0.2408
3	WTI does not cause BRENT	0.174713	0.9164
	WTI does not cause MCE	0.352292	0.8385

Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico. MCE: Mexican crude oil exports, WTI: west Texas intermediate

Table 4: Variance decomposition

Number of Periods	MCE	BRENT	WTI
1 Period	89.11	100.00	86.43
5 Periods	81.81	91.32	77.76
10 Periods	81.81	91.31	77.76

Source: Authors' own elaboration with data from the National Hydrocarbons Commission of Mexico. MCE: Mexican crude oil exports, WTI: West Texas intermediate

itself, The MCE contains 82% and the WTI 78% of the variance, which shows great volatility after that same period (10 months).

4. CONCLUSIONS

The evidence of cointegration among Mexican, American and European crude oil prices shows that there exists a long-term relationship. That is, non-stationary variables are cointegrated and tend to move together without departing too much from the long-run equilibrium with common trends among markets.

Brent crude is the one that determines the trend in greater extent during the period 2005-2016. It is worth mentioning that these trends can be eliminated insofar as it is possible to find stationary linear combinations formed by variables that are not individually stationary. Finally, the analysis of yield and risk of the three-crude oil shows that the oil offering the highest average yield is the Mexican crude, and the Brent provides the highest average RP.

The different analyzes carried out show that a long-term equilibrium relationship is maintained among the three crude prices studied. In particular, WTI and the BRENT cause in the sense of Granger to MCE, but the latter does not cause to WTI and BRENT. While the impulse-response functions indicate that positive and negative impulse stabilize between the sixth and the tenth period. Finally, the decomposition of the variance shows that deviations from equilibrium can occur from the 1st month to the last month of the period analyzed.

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