The relationship between oil and corn prices: Break-time versus regime-switching analysis

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Abstract: The objective of this work is to study the long-run relationship between corn and oil prices. It is based on the study of Elmarzougui and Larue [6], who studied the breaks in the regimes of these products. However, our research not only uses more data but also analyzes temporal breaks according to Markov regimes of Cointegration and breaks along the period. Both approaches identified a stable relation between prices due to the stationarity of the error; however, the Markov approach showed greater accuracy in the short-run, which represents a gain of information in this model.

Key-Words: Corn; Oil; Markov regimes; Cointegration; Temporal breaks; Commodities.

1 Introduction

The corn commodity and its use as an element of energy production as well as oil extraction have shown considerable growth in recent years [4]. The global demand for corn has been increasing most likely because of the economic growth of Asian countries and the use of this cereal in the USA for ethanol production. Oil can be considered a key element for economic growth and as a direct input in the production of agricultural output. Oil also plays an important role in manufacturing inputs and can be considered a very important item for the economy.

In this context [3, 10] explored the oil price-real exchange rate relationship and found a causal relationship between both. Uddin and Tiwari [10, 12] concluded that the strength of movement of the change in exchange rate and oil price differences varies over the time horizon in the researched period. Furthermore, Akram and Mortazavi [1] analyzed the effects of crude oil price changes on the economic growth of India, Pakistan and Bangladesh, and the results show that only India's economic growth is significantly affected when crude oil prices decrease.

This study broadens the research of Elmarzougui and Larue [6], who tried to identify the relationship between corn and oil through structural breaks in time from January 1957 to April 2009. This study extends their research by examining the period from January 1957 to January 2013 and by proposing an alternative approach that uses the cointegration technique of Markov regime changes.

This study is divided into five sections. After the introduction, the section 2 is discussed through Markov's regimes and the break in time model. The third section presents an analysis of which model has shown the best relation between oil and corn; considerations are given in forth section and, finally, the conclusion in firth section.

2 Methodology

Oil and corn prices have been collected on a monthly basis by the International Financial Statistics (IFS) of the International Monetary Fund (IMF) with the objective of studying the relation of oil and corn prices in the long-run considering the existence of different regimes. These data along with the research of Elmarzougui and Larue [6] were used. The data covers January 1957 to January 2013. First, the presence of unit root and stationary data was verified through the ADF-GLS [5] and KPSS tests [9]. The ADF-GLS test evaluates the null hypothesis of non-stationarity, while KPSS tests the null hypothesis of stationarity of a time series.

To elaborate the autoregressive model with Markov switching (MS-AR), it is necessary to determine the number of regimes and optimal lags [8]. The existence of regimes (1) has been determined by the linearity test with AIC Criteria.

The Markov's regime methodology attributes conditional probability p to a variable within a determined regime and probability (1-p) within another regime [11].

$$LnCorn_t = \begin{cases} \alpha_{0,st} + \sum_{n=1}^{p} \beta_{0,st} Ln_{oil} + \varepsilon_{0t} if st = 0 \\ \alpha_{1,st} + \sum_{n=1}^{p} \beta_{1,st} Ln_{oil} + \varepsilon_{1t} if st = 1 \\ \alpha_{2,st} + \sum_{n=1}^{p} \beta_{2,st} Ln_{oil} + \varepsilon_{2t} if st = 2 \\ \alpha_{3,st} + \sum_{n=1}^{p} \beta_{3,st} Ln_{oil} + \varepsilon_{3t} if st = 3 \end{cases} \quad (1)$$

In Equation (1), $LnCorn_t$ the variation of corn prices, $\alpha_{i,st}$ is the constant, $\sum_{n=1}^{p} \beta_{i,st} Ln_{oil}$ is the variation of oil prices, ands is a Markov chain with four states. By estimating MS-AR, the transition probability matrix was obtained. After this estimation, we analyzed the long term relation with price level, estimated in log-values. After the short-run dynamics analysis, the variation of prices was determined by considering log-returns.

The methodology we use to analyze the possible effects of temporal breaks in the long and short-run relationship between the variables can be considered alternative if compared to the methodology used by Elmarzougui and Larue [6]. A procedure to identify the breaks, following Zeileis, Patnaik and Shah [13] was developed using the negative log-likelihood criterion and LWZ information, Equation (2).

$$Ln\, Corn_t^k = \alpha^k + \beta^k Ln_{oil_t} + \varepsilon_t^k \quad (k = 1,2,3) \ (2)$$

In Equation (2), $Ln\, Corn_t^k$ is the change in the price of corn and $\beta^k Ln_{oil_t}$ is the change in the oil prices; k structural breaks are defined by the

3 Results

Markov-switching. First, the stationary property of the variables in level was tested using unit root tests according to ADF-GLS and KPSS. A non-stationary behavior was found in level (ln-values) and was calculated in the 1st difference. The results are presented in Table 1.

According to Table 1, the null hypothesis is rejected for oil and corn, thus confirming the stationarity of the series, meaning that they are I (1) and 1st difference I(0) in level. By observing the mean values of the log-returns of corn and oil, we obtained values of 0.002 and 0.006, respectively. Oil presents greater returns than corn, as confirmed by the variance, and it is possible to see that the price of oil varies more than the price of corn. Only the kurtosis and asymmetry values for oil are high. After analyzing the variables by the estimated model, four distinct regimes were identified, as presented in Table 2, through the transition matrix.

Table 1. Unit root test and descriptive statistics of returns of corn and oil.
(1957:03 – 2013:01 monthly observations)

	d_corn	d_oil
Unit Root Test		
ADF-GLS (p-value)	0.006	0.000
KPSS (p-value)	>0.100	>0.100
Descriptive Statistics		
Mean	0.002	0.006
Standard Deviation	0.053	0.086
Variance	0.003	0.007
Kurtosis	3.688	95.116
Asymmetry	-0.046	5.966

Notes: d_corn is the variation of corn's ln-prices; d_oil is the variation of oil's ln-prices

Table 2. Transition probabilities p{i|j} = P(Regime i at t+1 | Regime j at t)

	Regime 0,t	Regime 1,t	Regime 2,t	Regime 3,t
Regime 0,t+1	0.9019			
Regime 1,t+1		0.8684		
Regime 2,t+1			0.8920	
Regime 3,t+1				0.9498

According to the transition probability matrix, all of the regimes are persistent, in other words, the probability of remaining in the actual regime is very high. The probability of remaining in Regime 0 is 90.19%, and the probability of remaining in Regime 1 is 86.84%. There is an89.20% chance of remaining in Regime 2. The probability of remaining in Regime 3 is the highest, at94.98%. A tendency to remain in the regime can be found because no frequent utterances are expected.

Based on the results obtained, the total temporal classification in regime 0 is 133 months (19.76%), with an average length of 11.08 months; Regime 1is244 months (36.26%), with an average length of 8.41 months; Regime 2is 209 months (31.05%), with an average length of 9.50 months; and Regime 3 is 87 months (12.93%), with an average length of 17.40 months. Figure 1 presents the regimes graphically.

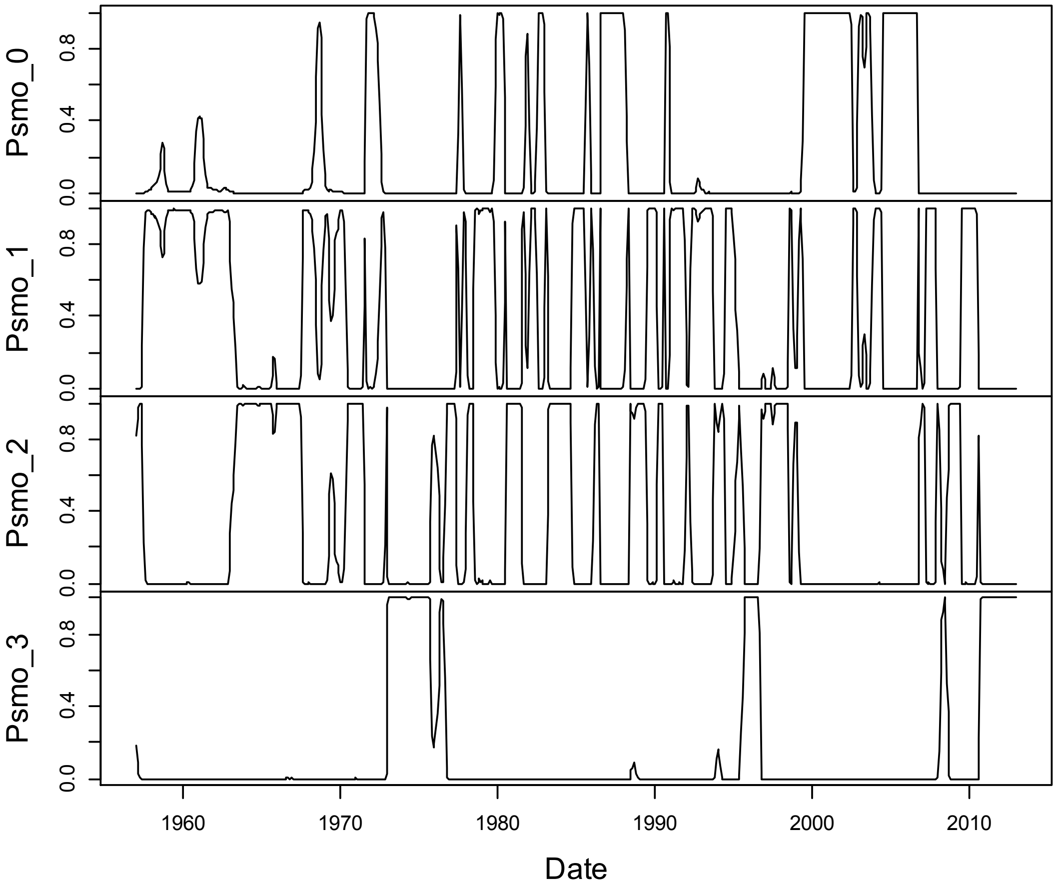

Figure 1. Graphical identification of regimes in Markov's model considering the ln-prices of corn and oil (1957:03 – 2013:01 monthly observations)

After identifying the existence of different regimes, we sought to determine whether the long-term relationship is stable. Table 3 presents the results for the long-run relationship between corn and oil, where four Markov regimes were found.

Table 3. Long-term relationship with Markov regimes (ln Corn x ln Oil) (1957:03 – 2013:01 monthly observations)

	Coefficient	Std. Error	t-value	p-value
Regime(0)				
Constant	3.6959	0.0275	134.0	0.000
Oil	0.2483	0.0089	27.8	0.000
Regime(1)				
Constant	3.7155	0.0113	328.0	0.000
Oil	0.3125	0.0041	75.8	0.000
Regime(2)				
Constant	3.8408	0.0116	330.0	0.000
Oil	0.3249	0.0047	68.7	0.000
Regime(3)				
Constant	4.0880	0.0463	88.2	0.000
Oil	0.3313	0.0121	27.4	0.000

Notes: Test residuals of ADF_GLS -5.2457 (0.000) and KPSS 0.0428 (5% = 0.462; 1% = 0.742);
Linearity LR-test Chi^2(10) = 1203.5 [0.000].

Based on the results from Table 3, it can be observed that in the first regime the impact of oil on corn is 0.2483 positive; in the second regime, the impact is 0.3125 positive; in the third regime, the impact is 0.03249 positive; and in the fourth regime, there is a positive impact of 0.3313.

The strongest relationships between corn and oil are found in regimes 0 through 3. To test whether the relation found is valid, the stationarity of the error was tested through the ADG-GLS and KPSS tests, which shows the error's stationarity. Thus, there is a long-term relation, but it oscillates among the regimes.

Elmarzougui and Larue [6] found that the regimes are in time, and in each time period there is a regime, unlike in Markov, where different regimes vary overtime. After finding a long-term relationship between the significant variables and that the error as stationary, we sought to identify the short-term relationships of these regimes. To do so, we analyzed the ECT (Error Correction Term) through the VEC. The analysis was no longer performed for the 1st change, allowing us to determine how the variation of oil affects the variation of petrol and the variation of petrol on oil in the short term.

Dynamics errors in the long-term were found in the short-term (ECT_1), indicating that the imbalance in long-term pricing is used to correct the short-run dynamics; if this relationship is significant, it is valid. In this context, the estimated short-run relationship presupposes robustness against heteroscedasticity and autocorrelation (HAC), as shown in Table 4.

Table 4. Estimation of the linear VECM with ECT's long-term relationship with Markov regimes. Standard errors HAC (1957:03 – 2013:01 monthly observations)

	d_corn		d_oil	
	Coefficient	p-value	Coefficient	p-value
Constant	0.0017	0.4003	0.0049	0.1502
ECT_1	**-0.1917**	0.0000	**0.2208**	0.0466
d_corn_1	**0.3365**	0.0000	-0.0328	0.6527
d_oil_1	-0.0294	0.2844	**0.2011**	0.0127
R-squared	0.1340		0.0581	
Adjusted R-squared	0.1301		0.0538	
F(3. 667)	30.0139	0.0000	7.9415	0.0000
Log of Likelihood	1068.4370		713.4172	
Akaike Criteria	-2128.8750		-1418.8340	
Ljung-Box Q'(5)	1.8706	0.8670	1.5524	0.9070

Notes: d_corn is variation in the ln-price of corn; d_oil is variation in the ln-price of oil.

When analyzing the ECT, the error in the relationship considering various regimes shows that the variation of corn is negatively influenced by 0.1917 in the imbalance and long-term variation in the price of corn, which is positively influenced by its previous variations at 0.3365, both significant influences. The change in the price of corn is not influenced by changes in the price of oil. An autocorrelation in the fifth order is not presented (Ljung-Box Q'(5)). The analysis of the variation in oil shows that it is influenced only by long-term imbalance (0.2208 positive) and its variation above (0.2011 positive). It has been found that the variation of corn does not affect the oil variation, and the variation of oil does not affect the corn variation in the short term, which has a stable relationship in the long-run oscillating among the regimes. In the short-run dynamics, neither presents causality.

Regime with temporal breaks. We applied the procedure for identifying breaks developed by [13] with negative log-likelihood and LWZ information criteria, and three breaks were found. We chose four segments with three intervals to ensure a higher number of observations in each segment. Figure 2 graphically presents the three breaks found in the temporal regimes.

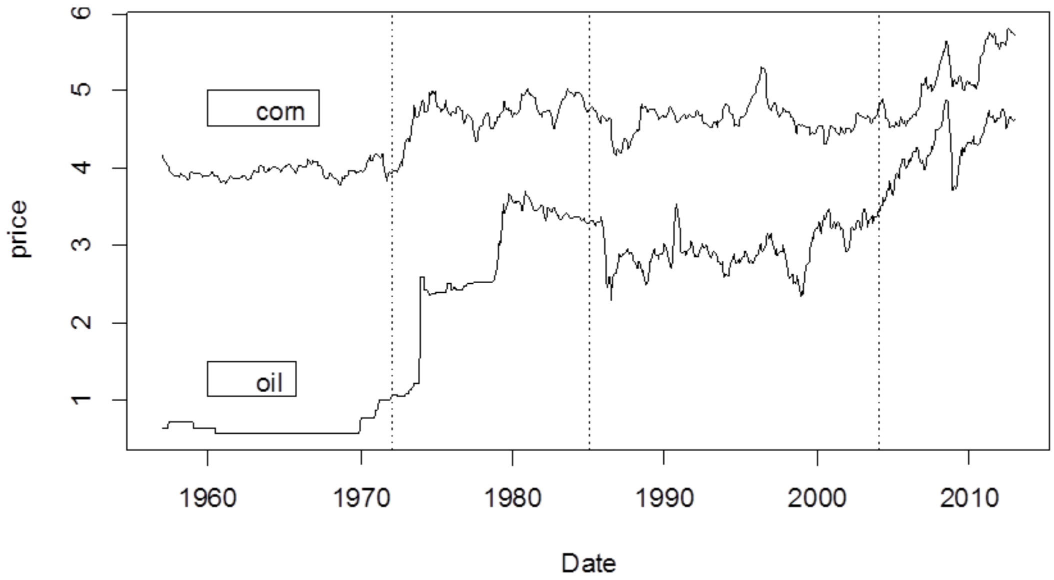

Figure 2. Graphical identification schemes assuming temporal breaks in different periods of time in the ln-prices of corn and oil (1957:03 – 2013:01 monthly observations)

The first break occurred in December 1972, the second in January1985 and last break in September 2004. The temporal breaks originally obtained by the authors occurred in January 1979, December 1987 and November 1999.

The first break (December 1972) corresponds to the period before the first oil crisis in 1973. In the early 1970s, oil producing nations began to regulate the flow of oil production because of its non-renewable nature and because the international demand for oil began to exceed its production. In the same period, there was a devaluation of the U.S. dollar in addition to the loss of its parity against gold, decreed by President Nixon in 1971. The second break (January1985) occurred when the agricultural markets were heavily distorted by protectionist policies during the 1980s. Another economic factor during this period was the military conflict, started in 1980, between Iran and Iraq, two major oil producers. On September 22, 1980, Iraqi armed forces invaded western Iran, claiming control of Khuzestan, the Iranian province richest in oil. Both sides were victims of air raids on towns and oil wells. Additionally, Petrobras in Brazil found important reserves of oil in Bacia de Campos in 1984, where it discovered the giant field of Albacora and, the following year, the Marlin field. The third break (September 2004) coincided with a decrease in oil production and an increase in its demand. The result was a peak in global oil prices, where from 2004 the world oil production remained within 5% of its peak despite historically high prices.

After this procedure, the long-term relationship between corn and oil prices was evaluated to identify whether they are stable, as found in Table 5.

Considering the breaks found, for the period from January 1957 to December 1972, the impact of oil on corn is positive at 0.1823; for the break found from January 1973 to January 1985, the impact is positive at 0.1088; and for the period from October 2004 to January 2013, the third break, there is a large positive impact of 1.0818.

Table 5. Long-run relationship with temporal breaks (ln Corn x ln Oil)
(1957:03 – 2013:01 monthly observations)

Regimes	Period	Coefficient	Std. Error	t-value	p-value
Regime(0)	1957:01-1972:12				
Constant		3.8462	0.0290	132.3830	0.0000
Oil		0.1823	0.0423	4.3110	0.0000
R-squared		0.0891			
Regime(1)	1973:01-1985:01				
Constant		4.4418	0.0486	91.332	0.0000
Oil		0.1088	0.0164	6.608	0.0000
R-squared		0.2266			
Regime(2)	1985:02-2004:09				
Constant		4.6670	0.1302	35.8440	0.0000
Oil		-0.0086	0.0435	-0.1980	0.8440
R-squared		0.0002			
Regime(3)	2004:10-2013:01				
Constant		0.5065	0.3165	1.7852	0.1130
Oil		1.0818	0.0731	14.7989	0.0000
R-squared		0.6909			

Notes: Test residuals of ADF_GLS -3.7671 (0.0001) and KPSS 0,0862 (5% = 0.462; 1% = 0.742).

All results are significant. The only time when this impact was not significant was from February1985 to September 2004. One of the influencing factors may have been the beginning of ethanol production, which emerged during this period. Furthermore, according to the Informal Economics FNP [7], the high value of corn in the United States was caused by the breakdown of U.S. crops and stocks, which caused an increase in the cost of ethanol production.

Another method was used to test whether the relationship is valid where the error fund is stationary. Through the ADF_GLS and KPSS tests, it was found that the error is stationary and the model is appropriate. After finding a significant long-run relationship between the variables and that the error as stationary, we estimated the short-term relationship through the VEC. In this estimation, the presence of heteroscedasticity and autocorrelation (HAC) is considered robust, as shown in Table 6.

Table 6. Estimation of the linear VECM with ECT's long-run relationship with temporal breaks. Standard errors HAC (1957:03 – 2013:01 monthly observations)

	d_corn		d_oil	
	Coefficient	p-value	Coefficient	p-value
Constant	0.0017	0.3784	0.0049	0.1569
ECT_1	**-0.0598**	0.0001	0.0286	0.0983
d_corn_1	**0.3141**	0.0000	0.0154	0.8441
d_oil_1	-0.0163	0.5680	**0.1816**	0.0431
R-squared	0.1146		0.0352	
Adjusted R-squared	0.1106		0.0309	
F(3.667)	23.5263	0.0000	2.6986	0.0449
Log of Likelihood	1060.9820		705.3921	
Akaike Criteria	-2113.9640		-1402.7840	
Breusch-Godfrey(12)	1.1705	0.3010	0.9741	0.4720
Ljung-Box Q'	9.2395	0.6820	8.5211	0.7430

Notes: d_corn is the variation in the ln-price of corn; d_oil is the variation in the ln-price of oil.

When analyzing the short-run dynamics to explain the variation of corn, an influence of -0.0598 ECT_1 in the long term is noticed, and the variation in the price of corn is positively influenced by its previous variation of 0.3141, which are both significant influences. By analyzing the variation in oil, it appears that it is only influenced by positive previous variations of 0.1816, and the imbalance does not affect the long-run oil variation. It emerges that the variation of corn does not affect the variation of oil and that the oil change does not affect the variation of corn in the short-run.

4 Discussion

After finding that both models proposed are adequate to explain the relationship between corn and oil prices, they were analyzed to choose the most suitable model to explain this relationship. When analyzing the results in the long-run relation with temporal breaks, the impact found in the relationship between the price of corn and oil was lower with the Markov regimes.

By analyzing the short-run dynamics of the temporal breaks, the variation of corn is affected by the correction of its imbalance and its long-run variations in previous periods were also found by the Markov regimes, but the first model explained 11.06% the variations of corn, while the Markov model explained 13.01%. The variation of corn in the Markov regimes is influenced by long-run imbalance, and it better explains this relationship. Similarly, when analyzing the relationship in the variations of oil, the temporal breaks model explained 3.09%, while the Markov regimes explained 5.38%. Thus, in the short-run relationships, the Markov regimes showed an influence of 0.1917 in the long-run, and the variation of corn has an influence of 0.3365. Broken down by time, the long-run imbalance has an effect of 0.0598, while the variation of corn is 0.3141 in the previous model.

The Markov regimes showed a higher influence in the variation of corn prices from the imbalance of the two variables, and it represents a gain of information. Lastly, both approaches show that the ratio of corn and oil and their prices are stable in the log-run in chosen. However, the Markov model showed greater precision when defining the short-run dynamics.

5 Conclusion

The relationship between corn and oil prices has become an economic concern because of the high increases in commodity prices observed in the first part of 2008, the fall of 2010 and the fall of 2012. This is mainly due to oil being an important input for grain production and the manufacture of chemicals used in agriculture. Thus, the main objective of this research is to study the relationship between corn and oil prices, and it expands the research of Elmarzougui and Larue [6] in two aspects: the sample size and the use of an alternative approach using the technique of cointegration with Markov regime changes, which, according to the results, can be considered the most explanatory model for this relationship.

The results explain the relationship between corn and oil prices, and the model proposed using the Markov regimes had a higher influence on the variation of corn's prices from the imbalance of the two variables and greater precision in defining the dynamic in the short run. This represents a gain of information compared with the temporal breaks model. It is worth stating that both explain the relationship expected because of the stationarity of the error. Furthermore, no causal link was found between the variations in corn and oil prices in either model.

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