Asymmetry between Gasoline and Crude Oil Prices in the Brazilian Economy and Some Selected Developed Economies

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2014

ASYMMETRY BETWEEN GASOLINE AND CRUDE OIL PRICES IN THE BRAZILIAN ECONOMY AND SOME SELECTED DEVELOPED ECONOMIES

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Abstract

The objective of this work is to study the gasoline prices evolution and its relationship between crude oil prices in the international market through causality and cointegration tests and across regression models of asymmetric, specifically this work uses stochastic models with heteroskedasticity and error correction mechanisms when it is mandatory. To achieve the purpose the purpose of this work, the gasoline prices were collected in Brazil, the USA and in a selected sample of six European countries namely Belgium, France, Germany, Italy, the Netherlands and the United Kingdom markets. All results are comparing among the markets selected to observe country similarities. All prices information collected were converted into U.S. dollars per liter. The data covers the period from June 2006 to April 2013.

Keywords: Cointegration; Asymmetry; Gasoline Price; Crude Oil Price.

1 Introduction

The evolution and association of crude oil and its byproduct prices are important for firms and economic policy makers. Therefore the studies of the relationship between gasoline and crude oil prices should allow to obtain fair gasoline prices in a particular market once petroleum product prices differ among regions and countries. This difference among oil product prices, in particular gasoline prices, occurs for three possible reasons: (i) production or prospection costs and oil transportation to refineries are different; (ii) refining cost or margin profit of byproducts production varies; and (iii) fees and taxes differs among regions or countries.

The Several studies have been developed in recent years in national markets to verify: the cointegration between crude oil and gasoline prices; crude oil predictive power to estimate gasoline prices; the crack spread or profit margin determination that differs among markets; and the relationship between gasoline and oil prices as they occur in each market, highlighting the asymmetry amongst these prices or returns. Among studies that verify the asymmetry this hypotheses sometimes were rejected. In a pioneer work Bacon (1991) studies the rockets and feathers effect in the United Kingdom gasoline market from 1982 to 1989, finding evidence that the response to positive changes in crude oil prices fluctuations on gasoline prices occur more rapidly than negative variations. The same evidence was presented by Karrenbock (1991) and Borenstein et al. (1997) in the North American market. Brown and Yücel (2000) observe the same asymmetric effect in the U.S. market. On the other hand Galeoti et al. (2003) revisit the rockets and feathers effect pointed out by Bacon (1991) and did not find similarities among asymmetric effects shown by Bacon (1991). The study developed by Galeoti et al. (2003) used monthly data from 1985 to 2000 for the European gasoline markets namely: Germany, France, the United Kingdom, Italy and Spain. This work differs from other studies. It is must be highlighted that Radchenko (2005) work that studies the effect of the crude oil prices volatility on the asymmetry degree in the gasoline prices response. In this study Radchenko (2005) used several time series models to indicate an evidence of asymmetry degree in gasoline prices that decreases when crude oil prices volatility increases. In other relevant work Honovar (2009) used cointegration techniques and error correction models, suggested by Granger and Yoon's (2002), to study the gasoline prices behavior using monthly data from 1981 to 2007. Among other inferences, Honovar (2009) indicates that the of gasoline prices behavior presents an asymmetry related with the crude oil prices variations. Liu et al. (2010) used asymmetric error correction models to examine how the gasoline and diesel prices were affected by crude oil price variations The data used for this work was petroleum weekly data from 2004 to 2009 in New Zealand. Unlike results obtained with diesel Liu et al. (2010) found no evidence of asymmetry in gasoline prices. Valadkhani (2010) studied gasoline prices traded on the Australian market and demonstrated evidence of the existence of asymmetry reported by Bacon (1991) in four Australian cities. In another study Valadkhani (2013) studied gasoline prices negotiated in the Australian market, with data from 2007 to 2012. In this other study Valadkhani (2013) accepted the hypothesis of asymmetric effect shown by Bacon (1991) in 28 locations and the existence of an opposite effect contrary to that obtained by Bacon (1991) in 31 Australian locations.

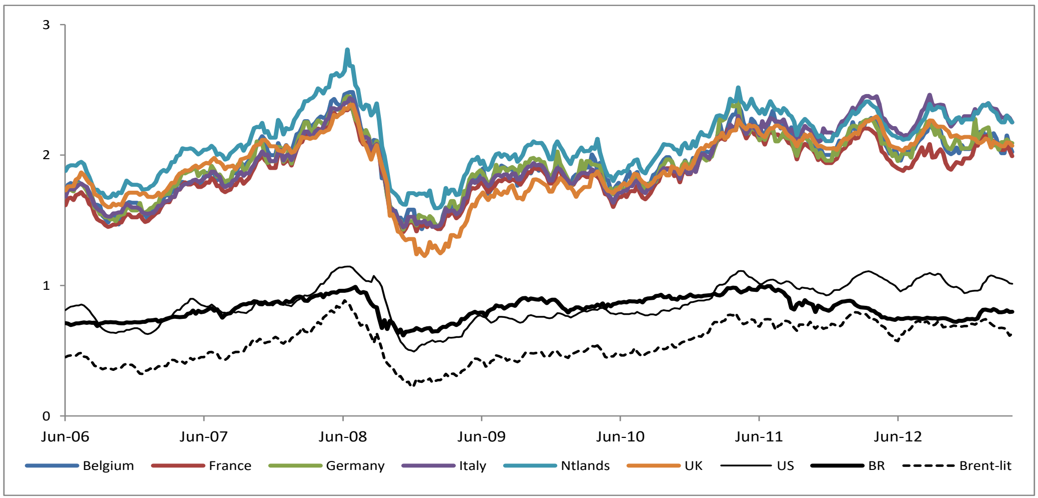
The objective of this work is to study the gasoline prices evolution and their relationship between crude oil prices in the international market through causality test and cointegration test and regression models of asymmetric. This work specifically uses asymmetric models with heteroskedasticity and error correction mechanisms when mandatory. To achieve the purpose of this work, gasoline prices were collected in Brazil, the USA and a selected sample of six European countries namely Belgium, France, Germany, Italy, the Netherlands and the United Kingdom markets. All results are compared among the selected markets to observe country similarities.

This work is structured as follows. Next section presents the sample used in this work. The methodological approach is explained in Section 3 while the results obtained are presented in Section 4. Finally Section 5 shows the final remarks of this work.

2 The Data Used

To reach the objectives of this work studies crude oil such as Brent type traded in the international market and gasoline weekly prices time series were collected from selected country markets. Primary data were obtained in the Brazilian Oil and Gas Government Agency (ANP) and the Energy Information Administration (EIA), official agency of statistics energy from the US government. All prices information collected were converted into U.S. dollars per liter. The data covers the period from June 2006 to April 2013. This information adds up to time series with 358 observations.

Figure 1 - Weekly Gasoline Price Time Series



The Figure 1 presents a plot to compare the gasoline price time series with crude oil prices time series. This plot shows that the gasoline prices variations were close among the markets studied in general. Other possible inference from this plot was an increase before and a sharp fall after 2008 crisis verified in the gasoline and crude oil prices demonstrating the similarities between the time series studied here.

Table 1 below presents a statistical summary of the gasoline price time series used in this work. This table also presents the normality and stationarity test results.

Table 1 - Gasoline Weekly Prices Time Series Statistical Summary

Statistics	Brazil	US	Belgium	France	Germany	Italy	NL	UK
Mean	0.8234	0.8672	1.9410	1.8709	1.9377	1.9599	2.0980	1.9169
Median	0.8281	0.8506	1.9417	1.8783	1.9496	1.8994	2.0817	1.9364
Maximum	0.9968	1.1465	2.4832	2.3643	2.4551	2.4621	2.8108	2.3881
Minimum	0.6186	0.4940	1.4318	1.4107	1.4292	1.4450	1.5930	1.2258
Std. Dev.	0.0889	0.1565	0.2400	0.2278	0.2321	0.2774	0.2426	0.2575
Skewness	-0.0631	-0.1947	-0.1245	-0.1204	-0.1898	0.0199	0.0094	-0.6352
Kurtosis	2.0712	2.2026	2.3323	2.2244	2.3665	1.8347	2.4468	2.8597
JB test	13.0692	11.7142	7.5542	9.8115	8.1132	20.2211	4.5573	24.3012
(p-value)	(0.0015)	(0.0029)	(0.0229)	(0.0074)	(0.0173)	(0.0000)	(0.1024)	(0.0000)
ADF test	-2.9758	-3.2527	-2.2301	-2.6145	-3.2073	-2.5739	-3.4954	-2.9808
(p-value)	0.1406	(0.0761)	(0.4709)	(0.2741)	(0.0847)	(0.2927)	(0.0414)	(0.1391)
Lags	9	2	0	3	7	3	12	12
N	357	357	357	357	357	357	357	357

The Jarque-Bera (JB) and the Augmented Dickey Fuller (ADF) tests were used to verify respectively the normality and stationarity hypothesis of the time series studied. Regarding the statistical summary of the gasoline price time series used in this work and also the normality and stationarity test results, it shows that the averages and medians present small differences. Considering the means obtained the lowest average price among gasoline price time series in the studied period occurs in Brazil followed by the US and the biggest price occurs in Italy followed by the Netherlands. The standard deviations were between 0.0889 and 0.2575 which shows that the Brazilian market presents the lowest price variability while the United Kingdom presents the biggest. It must be highlighted that in the Brazilian and American markets the gasoline price variability was smaller than the other markets studied. In these other markets the variability presents similarities in general. All skewness coefficients differ from the normal distribution coefficient. Other than Italy and the Netherlands all skewness coefficients were negative. Apart from the United Kingdom the kurtosis coefficients of all gasoline price time series were around two, which indicates a lower kurtosis than the normal distribution. This way the values obtained for skewness and kurtosis coefficients differ from the normal distribution values. Moreover the Jarque-Bera test demonstrates that the normality assumption of all returns time series analyzed could not be accepted once the p value of this test was close to zero. The unit root ADF test showed a negative *t* statistic but with small values for every gasoline price time series analyzed. Hence all returns time series studied here could not be considered stationarity as shown by p-values, excluding the Netherlands whose the stationarity hypothesis could be accepted in a significance level near 5%. Brent type crude oil prices average in US$ per liter in the studied period was close to 0.56 for the Brent. The skewness and kurtosis coefficients obtained from the crude oil prices time series differ from the normal distribution coefficients which highlights that the crude oil price distribution differ from the normal distribution which is confirmed by the Jarque-Bera test.

Besides crude oil and gasoline prices, the returns of these prices were used in this work for asymmetric models implementation. This way the price return time series were calculated from the weekly prices presented above using the following formula:

$$R_t = Ln\left(\frac{P_t}{P_{t-1}}\right),$$

where R_t represents the return in the period *t* and P_t represents the price in period *t*.

The lowest price return among gasoline price return time series in the studied period occurs in Brazil followed by the US while the biggest price occurs in Italy followed by the Netherlands. The standard deviations were between 0.0187 and 0.0260 which shows that the Italian market presents the lowest price return variability while Belgium presents the biggest. It must be highlight that in Italy, the United Kingdom and France the gasoline price return variability's was smallest than the other markets studied. In other markets the variability presents similarities in general. All skewness coefficients differ from the normal distribution coefficient. All skewness coefficients were negatives while all gasoline price time series indicates kurtosis higher than the normal distribution. This way the values obtained for skewness and kurtosis coefficients differ from the normal distribution values. Moreover the Jarque-Bera test demonstrates that the normality assumption of all returns time series analyzed could not be accepted once the p value of this test was close to zero. The unit root ADF test showed a negative *t* statistic with high values for every price time series analyzed.

Hence all returns time series studied here could be considered stationarity as shown by p-values that the stationarity hypothesis could be accepted in a significance level lower than 1%.

3 The Methodological Approach

In order to investigate the asymmetric relationship between crude oil price returns or variation and the gasoline price variation of selected countries their cointegration was first tested. Therefore the cointegration among all the gasoline price time series and crude oil price time series were tested. WTI and Brent crude oil prices were used in this work. Two variables are cointegrated if their linear combination is stationarity, and as a consequence there is a long-run relationship between these variables. There are some alternatives to cointegration tests between two variables and in order to do so the Engle-Granger test which was presented in Engle and Granger (1987) was used in this work. The cointegration had relevant implications. If the variables involved are cointegrated it is possible to search for a model to explain or forecast one of these variables using the other as a regressor. Besides that, the knowledge of variables cointegration allows for the behavior study of these variables using an error correction mechanism in stochastic models. In other words, if the cointegration between two variables hypothesis can be accepted, the introduction of an error correction mechanism will be crucial for the estimation of stochastic model.

To achieve the main objective of this work, stochastic models for gasoline price returns were used having two variables: the crude oil prices positive and negative returns. These models demonstrated below take into consideration the time series problems: the no normality observed in the weekly time series of returns that present heavier tails than the normal distribution; and the heteroskedasticity of these series of returns. The t of Student distribution was chosen as an alternative to the normal distribution, in other words to accommodate abnormal observations. The t distribution has been widely used as a methodological approach which uses daily and weekly returns of financial assets due to the attractiveness presented in the form variations given by the degree of freedom numbers. To estimate the variance ARCH models were implemented. To achieve this several Autoregressive Conditional Heteroskedasticity (ARCH) family models are proposed. In this work, besides the ARCH model, first proposed by Engle (1982), the following models were tested: the GARCH model, a straightforward generalization of the ARCH process which also takes into account past lags of the conditional variance, first proposed by Bollerslev (1986); Exponential GARCH, proposed by Nelson (1991), which considers asymmetric shocks in the price returns; and IGARCH, proposed by Engle and Bollerslev (1986), a particular case of the GARCH model that is quite similar to the exponentially weighted moving average (EWMA) model. The following stochastic model was used in this work, an asymmetric model with error correction mechanism:

$$
\begin{aligned}
&(R_t | I_{t-1}) \sim Student(\mu_t; \sigma_t^2; \nu) \\
&\mu_t = \beta_1 ROil_t^- + \beta_2 ROil_t^+ + \beta_3 (GP - \beta_4 BP) \\
&\sigma_t^2 = ARCH
\end{aligned}
$$

This representation refers to the mean part of the regression but it is also important to put foward consistent processes to estimate the variance, or the volatility of the price returns.

In the next section the results obtained using this methodology are presented.

4 The Results Obtained

Table 2 covers the gasoline price of each country selected and the Brent type crude oil prices cointegration. These results were obtained using the Brent type crude oil prices as a dependent variable and an independent variable in the Engle-Granger cointegration test used here. This test null hypothesis specifies the non cointegration among selected gasoline prices and Brent type crude oil prices. Apart from the Brazilian gasoline market as shown in Table 2 the results of the cointegration test, that is, the tau statistic and their p value, indicates that the null hypothesis cannot be rejected for all the analyzed tests. Therefore when the Brent type crude oil price or returns are regressors in models to explain the gasoline prices, the mechanism of error correction must be introduced in the models as suggested by these results, excluding the Brazilian gasoline prices or returns.

Table 2 – Results of Cointegration Tests - Brent

Independent Variable	τ statistics	p-value	Dependent Variable	τ statistics	p-value
Brazil	-1.9856	0.5363	Brazil	-2.4680	0.2954
USA	-4.4529	0.0017	USA	-4.3151	0.0028
Belgium	-6.6949	0,0000	Belgium	-6.9236	0,0000
France	-5.2583	0.0001	France	-5.3709	0.0000
Germany	-4.6041	0.0010	Germany	-4.8726	0.0003
Italy	-4.8441	0.0004	Italy	-4.8119	0.0004
Netherlands	-4.6398	0,0008	Netherlands	-4.7812	0,0005
United Kindom	-4.2991	0,0029	United Kindom	-4.2789	0,0032

Table 3 – Results of Asymmetric Models

Country	***β₁*** *(p-value)*	***β₂*** *(p-value)*	***β₃*** *(p-value)*	***β₄*** *(p-value)*	*AIC*	*g.l.* *(p-value)*
Brazil	0229 (0.000)	0.055 (0.133)	0.0174 (0.000)	1.124 (0.000)	-5.37	5.42 (0.00)
USA	0.035 (0.000)	-0.024 (0.552)	-0.060 (0.047)	1.108 (0.000)	-5.32	5.95 (0.00)
Belgium	0.326 (0.000)	-0.028 (0.593)	2.640 (0.034)	2.993 (0.007)	-4.55	16.72 (0.11)
France	0.247 (0.000)	0.048 (0.217)	0.006 (0.102)	2.285 (0,000)	-5.13	9.00 (0.02)
Germany	0.327 (0.000)	0.0724 (0.116)	0.008 (0.039)	2.546 (0.000)	-4.66	8.42 (0.01)
Italy	0.215 (0.000)	0.103 (0.004)	0.000 (0.998)	609.64 (0.998)	-5.32	9.40 (0.04)
Netherlands	0.242 (0.000)	0.165 (0.000)	-0.000 (0.100)	3803.0 (0.999)	-5.25	8.22 (0.00)
UK	0.226 (0.000)	0.053 (0.112)	0.004 (0.100)	2.156 (0.001)	-5.46	7.06 (0.00)

For each gasoline market one model was selected for analysis. The model selection has been done initially observing the significance of conditional heteroskedastic model, or the ARCH model used in the estimation of gasoline price return variation from each selected markets. From this stage the following criteria for model selection was take into consideration in the following order: the Akaike criteria, the Schwarz criteria and standard error of the model. Among the selected models where the Brent crude oil is an explanatory variable it can be observed that statistically significant coefficients of the variable that represents the negative variations of crude oil prices or returns while the coefficients of the variable that represents the positive variations of crude oil prices are not in general statistically significant as shown in Table 3. This is an indication that the asymmetry could not be rejected. Besides that the similarities were observed. Apart from Italy and the Netherlands the ECM does not present statistical significance. This way the asymmetric model was also estimated without the ECM and the results obtained indicate the same inference of Table 3.

4 Final Remarks

The results obtained in this work allow a comparison analysis of the evolution of gasoline prices in selected countries. Thus the relevant results obtained here suggest that other work on this topic with other samples and other statistical inference methods must be done to obtain other results which will help the economic agents dealing in the petroleum products determine a fair price and in the crude oil price forecasts. Thereby it is possible to obtain estimates for gasoline and others petroleum products fair prices among different regions or countries. Petroleum product and oil prices unlinked in certain periods turn the petroleum product fair price determination difficult which is harmful to the oil sector and consequently for national economies.

It can be stated that all objectives were achieved, as it was possible to establish coherent and consistent criteria to verify cointegration and asymmetry between each gasoline market selected and crude oil prices from a statistical point of view. It should be emphasized, though, that the results were taken for a specific time period and there may be significant differences when other data are taken into account. Besides, it is worth noting that other statistical inference methodologies may be proposed to investigate the relationship between the involved markets here studied, and the selection of the most appropriate econometric tests and asymmetry models.

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