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THE RELATIONSHIP BETWEEN CRUDE OIL PRICES AND EXCHANGE RATES

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ABSTRACT

Crude oil prices are influenced by several events that occur randomly, for example, the weather, the available stocks of oil, the economic growth, the variation in the industrial production, political or geopolitical aspects, exchange rate movements, and so on. Oil price volatility brings uncertainties for the world economy. Despite the difficulty in working with oil price time series, a lot of researches have been developing ways to better understand the stochastic process which represents oil prices movements. This work introduces an alternative methodology, with a Bayesian approach, for the construction of forecasting models to study the returns of oil prices. The methodology introduced here takes in consideration the violation of homoskedasticity and the occurrence of abnormal information, or the non-Gaussian distribution, in the construction of the price forecast models. Moreover, this work examines the relationship between crude oil prices and exchange rate through a cointegration test. The data used in this study consists of the daily closing exchange rate of US dollar to Euro, and oil prices of WTI, West Texas Intermediate, and Brent types, from January 2005 to March 2009. The results do not show the acceptance of cointegration hypothesis. With the presented models, it is possible to infer that the exchange rate is important to explain the oil barrel returns.

Keywords: Crude Oil Prices; Exchange Rate; Cointegration; Forecast Models.

1. INTRODUCTION

Crude oil price is an important and sometimes determinant variable for the economic policy makers of countries that have this commodity as a main source of energy as well as in those where crude oil price is part of their energy matrix. The crude oil prices volatility influences directly the international financial market and consequently the changes in the financing and the investments of productive activities. This was observed in the crises, in the seventies, and more recently in the significant movements of the crude oil prices in 2008.

As Wang et al. (2005) and Xie and Wang (2006) observe that crude oil prices are influenced by several events which occur in an irregular form, for example, the weather, available stocks, income, industrial production and political or geopolitical aspects. In a paper by Panas and Ninni (2000) on the volatility of the crude oil prices highlights that oil prices market has the highest volatility when compared to other financial markets. Thus the academics and practitioners recognize the difficulty and complexity in obtaining a crude oil price forecast model. As the volatility of oil prices implies uncertainties for global economy, it is necessary to minimize uncertainties regarding future crude oil prices and in spite of the already mentioned difficulty to work with the oil prices in time series, a lot of research has been carried out with the aim to establish a stochastic process that, in a better way, represent the movements in the crude oil prices or returns or the variations of these prices.

Another relevant variable that directly influences the international financial market is the exchange rate, specially the US\$/EUR. Thus this variable must have some relation with the to verify the relationship between crude oil prices and exchange rates. Some research about this has been done, for example, Chen and Chen (2007) and Sadorsky (2000). With the aim to obtain forecast models for oil prices, this work verifies the cointegration between crude oil prices and the exchange rate. This is done from the main types of crude oil price return time series, such as WTI and Brent, and the US\$/EUR exchange rate. Regarding the procedures of statistical inference this work introduces an alternative methodology from the models presented in the literature. The methodology introduced here for the crude oil price forecast models construction takes into consideration the heteroskedasticity and the occurrence of abnormal information, or the outliers, in the crude oil price or return time series. Thereby this work proposes an alternative methodology with a Bayesian approach in the construction of forecast models for returns of oil prices considering the heteroskedasticity and the non-Gaussian distribution. In addition that this research proposes a multivariate model to study the exchange rate contribution for forecasting crude oil prices.

Besides this introduction, the objective of this work is presented in next section. And the remaining of this work is organized as follows: Section 3 introduces the methodological approach used here; Section 4 describes the data or the sample used; Section 5 presents the results obtained while the Section 6 refers to the final remarks; and finally in the end the references used were presented.

2. OBJECTIVES

The objective of this work is to propose a methodology for the forecast models for crude oil price returns considering the heteroskedasticity and the non-Gaussian distribution. Besides that this work investigates the cointegration between time series of crude oil prices and the exchange rate with a stochastic unit root model. It also verifies the performance of a multivariate model for forecasting crude oil prices using the exchange rate as an explanatory or antecedent variable.

In order to achieve the objective of this work the methodological approach used is described in Section 3 next.

3. METHODOLOGY – AN ALTERNATIVE APPROACH

To accomplish the objective, models were constructed to study the movements of the returns of the closing quotations of crude oil prices spot market: for the West Texas Intermediate (WTI) and the Brent types negotiated in the New York and in the London markets, respectively. These models consider the characteristics that generally found in the financial assets return time series as the non-normality and the heteroskedasticity. The Student's t distribution was chosen as an alternative to the normal distribution, in other words, to accommodate the abnormal observations of weekly return series of the crude oil price main references in the international markets, namely the WTI and the Brent. The Student's t distribution has been broadly used, as the methodological approach which uses the daily and weekly returns of financial assets, because of the attractiveness presented by the form variations given by the number of degrees of freedom. The heteroskedasticity of the returns was dealt with heteroskedasticity models, in which a variance law was based in the Autoregressive Conditional Heteroskedastic Model—ARCH Model presented in the econometric literature by Engle (1982). This way autoregressive models were built, in a Bayesian approach, for the average returns with the variance of returns changing with time. The first model used, designated by Model 1,

was an AR(1)-ARCH(1) model, an autoregressive model for the average and an ARCH model for the variance, described in the following form:

Model 1

$$(R_t | I_{t-1}) \sim Student(\mu_t; \sigma_t^2, \nu)$$

$$\mu_t = aR_{t-1}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2$$

where:

- R_t = return of the closing quotation of oil price at time t ;
- I_t = available information until the time t ;
- μ_t = average of returns in the time t ;
- σ_t = standard deviation of the returns at time t and $e_t = (R_t - \mu_t)$.

Model 2

$$R_{it} \sim Normal(\mu_{Rit}; \sigma_{Rit}^2; \nu_{Ri})$$

$$R_{it} = a_{it} + b_{it} ExchangeRate_{it}$$

$$\sigma_{Rit}^2 \sim Gama$$

$$\nu_{Ri} \sim Uniforme$$

$$e_{it} = R_{it} - (a_{it} + b_{it} ExchangeRate_{it})$$

$$e_{it} \sim Normal(\mu e_{it}, \sigma_i^2)$$

$$\mu e_{it} = \rho_{it} \mu e_{it-1}$$

$$\rho_{it} = \exp(\omega_{it})$$

$$\omega_{it} \sim Normal(\mu_{\omega}, \sigma_{\omega}^2)$$

$$\mu_{it} = \mu_{\omega} + \varphi(\omega_{it-1} - \mu_{\omega})$$

For each i crude oil type as shown in the model the negative values for μ_{ω} indicate an expected ρ_{it} value lower than 1, which suggests a unit root process as observed by Congdon (2001). This way the series of the variable e_i is stationary therefore the crude oil price returns and the variation of the exchange rate are cointegrated.

The Model 1 was constructed in two ways: Model 1(a), with intercept in the variance equation, and Model 1(b), without intercept in the variance equation. The other two models used in this work were also built with a Bayesian approach. One of these models, designated in this work by Model 2, was constructed from a *Stochastic Unit Root Model* - STUR model, to examine the cointegration between crude oil prices and the exchange rate. The other model, designated here by Model 3, was constructed from a

Seemingly Unrelated Regressions Model - SUR model, as shown in Salles (2007), for forecasting the returns of crude oil prices types using this multivariate model with the exchange rate as an antecedent variable, or regressor, in the same time t of the returns and with lag 1, or at time $t - 1$. While the Model 1 used here was developed from the description of Generalized Autoregressive Conditional Heteroskedasticity—GARCH Model, in particular the GARCH (1,1) model presented in Akgiray (1989), the Model 2, presented above, was constructed from the STUR Model, as suggested in Granger and Swanson (1977), to test the cointegration between crude oil prices and the exchange rate, respectively, the crude oil type prices selected and the US\$/EUR exchange rate.

The third model is constructed to forecast crude oil price returns in a multivariate approach using the exchange rate as an exogenous variable at time t and time $t - 1$, respectively, for Model 3 in its different forms Model 3(a) and Model 3(b) which are mentioned henceforth in Section 5. This model is constructed from a SUR model with time varying parameters in the following form:

Model 3

$$\begin{aligned}
 R_{it} &\sim Student(\mu_{it}; \sigma_{it}^2; \nu_i) \\
 \mu_{it} &= \alpha_{it} + \beta_{it} ExchangeRate_{t-1} \\
 \alpha_{it} &\sim Student \\
 \beta_{it} &\sim Student \\
 \sigma_{it}^2 &\sim Gama \\
 \nu_i &\sim Uniforme
 \end{aligned}$$

For the every parameter posterior distribution determinations, numeric methods based on Monte Carlo Markov Chain (MCMC) were used. The developed models were implemented in the Bayesian Inference Using Gibbs Sampler Software - BUGS, in the WinBUGS 1.4 version, elaborated by Spiegelhalter et al. (2003) to obtain the posterior distributions using MCMC via Gibbs Sampling. The priori distributions used in all models were vague distributions, in other words, the variances of the priors were high. For a better understanding of the procedures of the Bayesian inference used in this work the reader can see Migon and Gamerman (1999).

After accomplishing the simulations with the models described previously this work compares models 1 and 3, through models selection criteria. The main selection criteria used in the models were the DIC criteria and besides that the Mean Square Error (MSE) and the Root Mean Squared Error (RMSE) were used. The Deviance Information Criterion (DIC) proposed in Spiegelhalter et al. (2002) and implemented in the BUGS software used in this work, is a generalization of the Akaike Information Criterion (AIC).

The selected model must minimize DIC obtained in the simulations for the posteriori distribution of the interest parameters and the other criteria used here.

The data used for the implementation of the models presented here are described in the next section.

4. THE DATA - THE SAMPLE USED

The data used for oil prices was the weekly prices collected on the Energy Information Administration-EIA, Official Energy Statistics from the U.S. government web site. From these data the crude oil price weekly returns was calculated in the following form:

$$R_t = \ln\left(\frac{price_t}{price_{t-1}}\right),$$

where R_t = return of the price at time t , $price_t$ = quote the price at time t , $price_{t-1}$ = quote price at time $t - 1$. The exchange rate weekly time series used here was collected from the European Central Bank web site and similarly to the crude oil price the exchange rate weekly variation was calculated . The data was collected from January 2005 to March 2009.

5. RESULTS OBTAINED

The posterior distributions were obtained from the implementation of previously presented models in the WinBUGS software. As previously observed, these posterior distributions were obtained through stochastic simulations based on Markov chain Monte Carlo (MCMC) via Gibbs Sampling. All results presented were obtained using vague priori distributions, that is, distributions with high variances for the priori distributions of the parameters. Moreover, it must be highlighted that the results were obtained after running 25,000 iterations and discarding additional 5,000 iterations as burn in period.

The figures presented below show the results of Model 1, an AR(1)-ARCH(1) model, that was estimated in two ways: the Model 1(a) and the Model 1(b). These models differ in variance equation, with and without an intercept. Figure 1 and Figure 2 show plots with the crude oil weekly returns time series versus the returns forecasts obtained

with Model 1(a) for WTI and Brent types, respectively. These plots show to see that the observed returns differ from the forecasted returns of the two crude oil types studied with the methodological approach used here. While for the time series of WTI type the MSE was close to 0.0248 for the Brent type was 0.0309. Regarding the Model 1(b), the equation without intercept in the variance, the results show a significant improvement regarding the Model 1(a), as it can be observe by the plots show in Figure 3 and Figure 4 that presented the results obtained with the Model 1(b) the MSE is close to 0.0091 and 0.0041 for the WTI and Brent types, respectively.

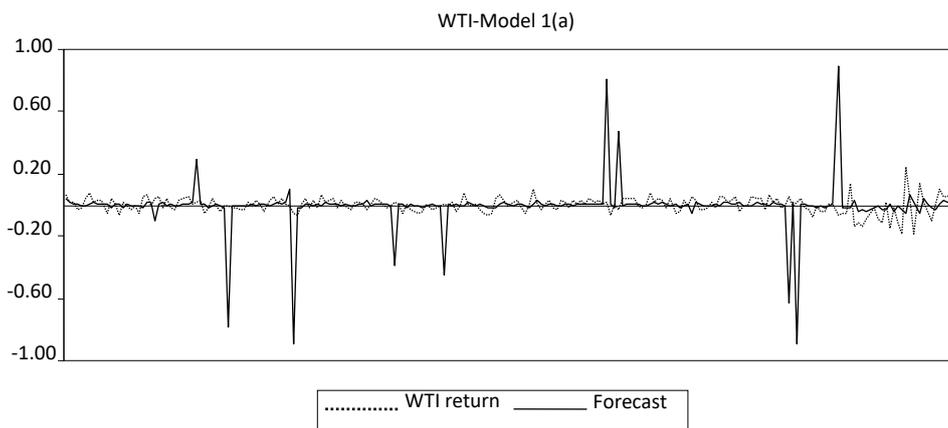


Figure 1 : Results of Model 1(a) AR(1)-ARCH(1) -- WTI return and Forecast.

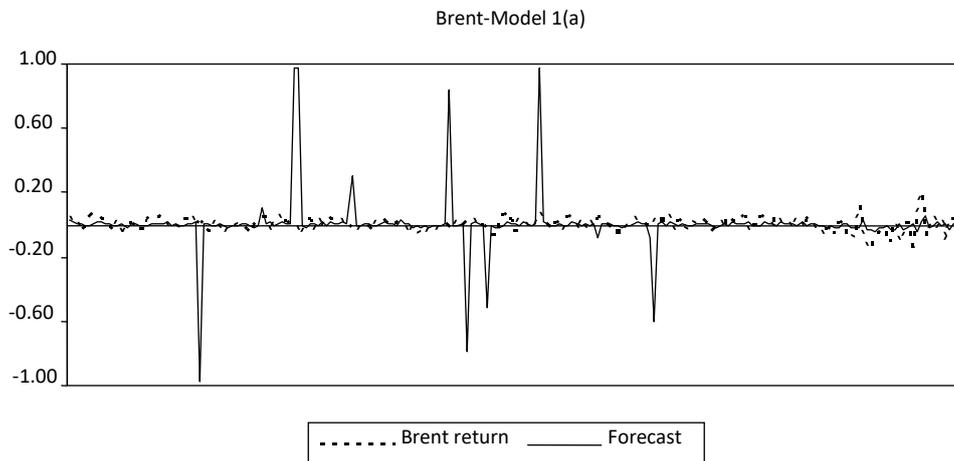


Figure 2 : Results of Model 1(a) AR(1)-ARCH(1) -- Brent return and Forecast.

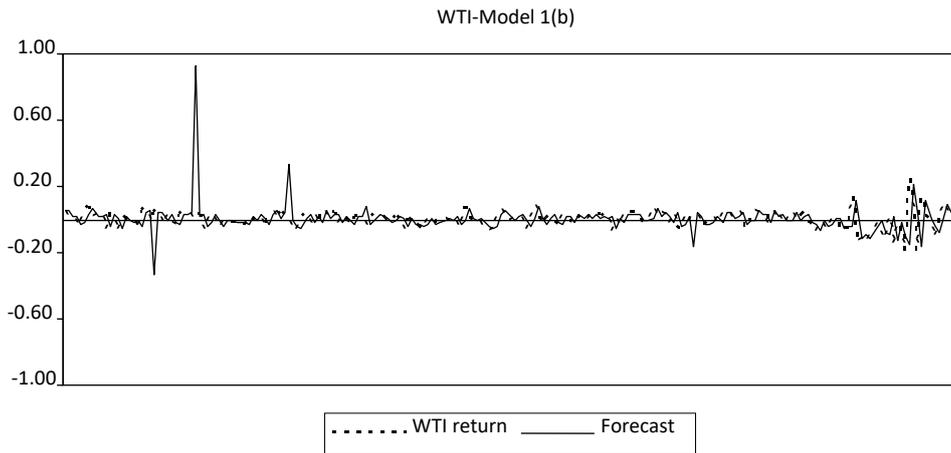


Figure 3 : Results of Model 1(b) AR(1)-ARCH(1) -- WTI return and Forecast.

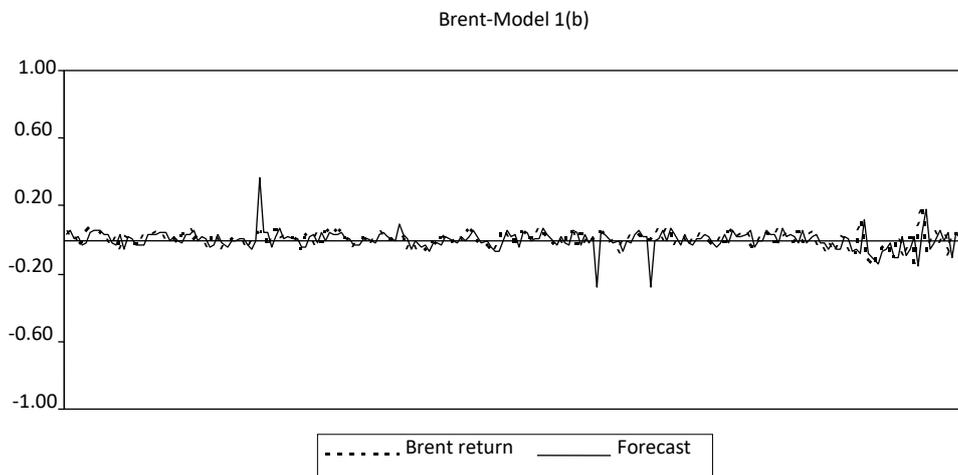


Figure 4 : Results of model 1(b) AR(1)-ARCH(1) -- Brent return and Forecast.

The results of the cointegration tests applied to examine the long-run co-movements between crude oil prices returns and the exchange rate are presented in the Table 1 and Table 2. In these tables it is possible to observe the mean and standard deviation of the posteriori distribution of the $\mu.\omega$ parameter related in the STUR Model and the probability of this parameter to be negative. This probability is given by PR whose average and the median are also listed in these tables.

From Table 1 it is possible to infer that the average probability of the cointegration between weekly returns of crude oil prices and the exchange rate variation was close to 0.4 and 0.5 to the WTI and Brent types, respectively. The median probability of this cointegration obtained in the stochastic simulation was 0 and 1, for returns of WTI and

Brent types, respectively, it must be highlighted the median of the cointegration probabilities obtained for the weekly crude oil prices of Brent type is the only indication of cointegration between the crude oil price returns and the exchange rate variations. Thus it cannot be affirmed from this test that there is cointegration of these variables, that is, between crude oil prices returns and the exchange rate. Regarding the association of these two variables with a classical measure of association product-moment correlation coefficient show that the returns series and the exchange rate are weakly associated, respectively, 0.27 and 0.32 for returns of WTI and Brent types with statistical significance.

Table 1 : Results of Cointegration Crude Oil Returns and Exchange Rate Variations

	WTI	Brent
<i>mu.omega</i>	0.000 (0.000)	0.000 (0.001)
<i>PR</i> mean	0.4	0.5
median	0.0	1.0
DIC	-572.72	-635.17

Table 2 : Results of Cointegration Crude Oil Prices and Exchange Rates

	WTI	Brent
<i>mu.omega</i>	0.005 (2.104)	0.000 (0.001)
<i>PR</i> mean	0.7	0.5
median	1.0	1.0
DIC	768.12	289.72

Table 2 shows the results obtained for inferences of the cointegration between the weekly crude oil prices time series and the exchange rate as well as these variables correlation. As shown on Table 1, in the Table 2 the observations for the parameter *mu.omega* are similar. The average probabilities of *PR* presented an indication of cointegration between WTI crude oil prices and the exchange rate in the period studied but this does not occur with the Brent type. The product-moment correlation coefficient however suggested a strong association between the exchange rate and crude oil prices of WTI and Brent types are 0.88 and 0.89 with statistical significance, respectively.

Figure 5 and Figure 6 show the results of Model 3(a) through plots which compare the observed and forecasted values of returns when the exchange rate is used as an independent variable in the same instant of time to the return, as shown in the model. The MSE is close to 0.0169 and 0.0215 for the returns of the oil prices of WTI and Brent

types, respectively. This way this model presented a better performance than the Model 1(a), but worse than the Model 1(b).

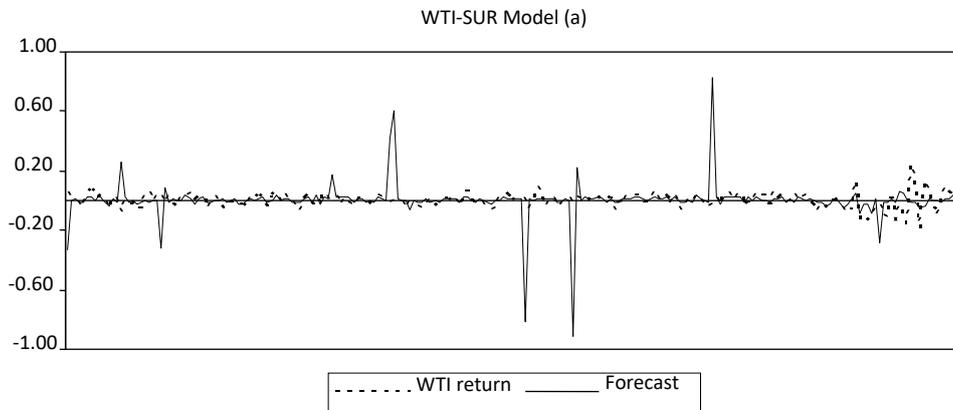


Figure 5 : Results of SUR Model 3(a) WTI return and Forecast.

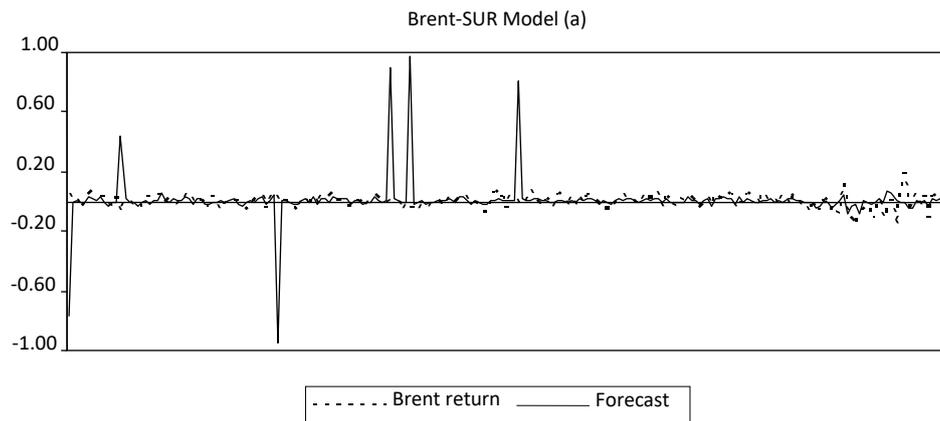


Figure 6 : Results of SUR Model 3(a) Brent return and forecast.

Figure 7 and Figure 8 presents the results obtained with the Model 3(b) , that is, the results obtained with the Model 3 using the exchange rate with lag 1 as an explanatory variable. The MSE performance indicator was 0.0268 and 0.0081 for the returns of oil barrel prices of types WTI and Brent, respectively. Thus, when the explanatory variable changed, the MSE increased for returns of the WTI crude oil price and decreased for the Brent type.

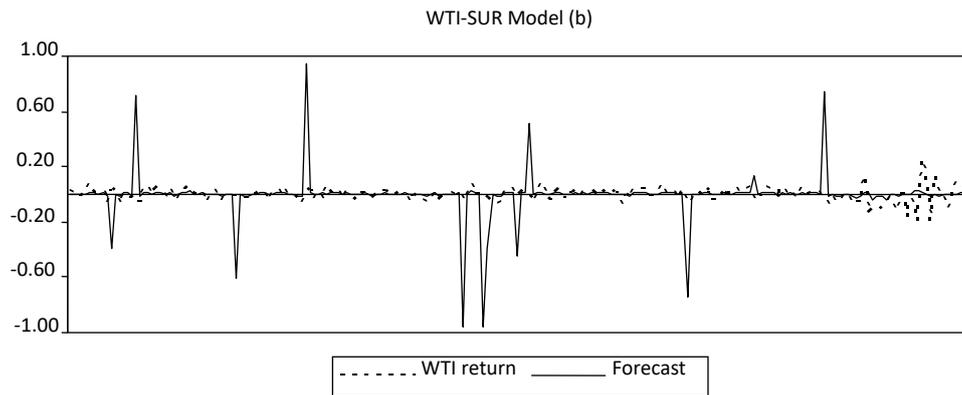


Figure 7 : Results of SUR model 3(b) WTI return and Forecast.

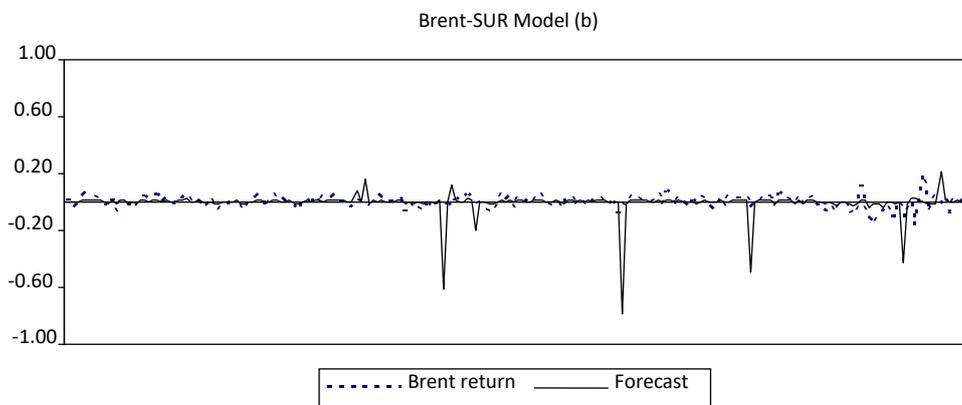


Figure 8 : Results of SUR model 3(b) Brent return and Forecast.

Table 3 : Summary of Models Performance

Model	WTI	Brent
AR(1)-ARCH(1) (a)	0.0248	0.0309
AR(1)-ARCH(1) (b)	0.0091	0.0041
SUR Model (a)	0.0169	0.0215
SUR Model (b)	0.0268	0.0081

Finally, Table 3 presents a results summary of the performance criteria of the models constructed for forecasting crude oil prices in this work. It must be highlighted that the model presented better performance to forecast crude oil future returns was the AR(1)-ARCH(1) in the formulation 1(b).

In the following section the final remarks of this work is presented.

6. FINAL REMARKS

The aim of this work was to verify the relevance of the exchange rate for crude oil price forecast models. This way the construction and estimation of forecast models for crude oil prices and price returns using the exchange rate as an explanatory variable was implemented.

The results obtained do not allow the acceptance of cointegration hypothesis between oil prices, or returns, and exchange rate. It was observed that the exchange rate does not improve the forecast models or turn these models more accurate. This happens also with an autoregressive model in which the best forecast performance metric was obtained. With the presented models here it is not possible to infer that the exchange rate is important to explain the crude oil barrel price returns. It must be highlight that the best forecast model performance was obtained with an autoregressive model, that is, the best performance among the models studied was the model that did not use the exchange rate as an explanatory variable.

This work seeks to contribute for the theme discussion that was dealt here. It is important mention that the inferences can be enlarged with the utilization of other models, other methodologies and other samples. Given the relevance of the theme dealt here, variables relevant to improve the crude oil price forecast, which is useful for those who participate directly in the market, that is, crude oil negotiators, or those who participate indirectly, firm and government planners, further research should be carried out to contribute to the literature related to the areas of finance and energy economics.

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