China-USA Business Review, ISSN 1537-1514
May 2012, Vol. 11, No. 5, 581-590

The Relationship Between Crude Oil Prices and Exchange Rates

Andre Assis de Salles
Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

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

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 volatility of crude oil prices 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 oil prices in 2008.

As Wang, Yu, and Lai (2005), and Xie, Yu, Xu, 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, they highlight that oil prices market has the highest volatility when compared to other financial markets. Thus, the academic and the practical professionals recognize the difficulty and complexity in obtaining a forecast model of crude oil prices. As the volatility of oil prices implies

Andre Assis de Salles, DSc., Associate Professor, Industrial Engineering Department of Polytechnic School, Federal University of Rio de Janeiro.
Correspondence concerning this article should be addressed to Andre Assis de Salles, Centro de Tecnologia-Bloco F/sala F-101, Cidade Universitária, Rio de Janeiro 21945-970, Brazil. E-mail: as@ufrj.br; aadesalles@gmail.com.

uncertainties for global economy, it is necessary to minimize uncertainties regarding future 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, represents the movements in the oil prices, or the returns or the variations of these prices.

Another relevant variable that directly influences the international financial market is the exchange rate, specially the US$-Euro exchange rate. Thus this variable must have some relation with the crude oil prices. So it's important to verify the relationship between crude oil prices and exchange rates. Some research about this has been done, for example, S. Chen and H. Chen (2007) and Sadorsky (2000). With the aim to obtain forecast models for oil prices, this work verifies the cointegration between crude oil prices and the exchange rate. This is done from the series of oil prices returns of each main types, WTI and Brent, and the US$-Euro exchange rate. Besides that this research proposes a multivariate model to study the contribution of the exchange rate for forecasting crude oil prices.

Regarding the procedures of statistical inference, this work introduces an alternative methodology, different from the models presented in the literature. In the construction of the forecast models of oil prices, the methodology introduced here takes into consideration the following: the heteroskedasticity; and the occurrence of abnormal information, or the outliers in the time series of the oil prices or of the returns of these prices. Thus this work proposes an alternative methodology, with a Bayesian approach, in the construction of forecast models for returns of oil prices. It is considering the heteroskedasticity and the non-Gaussian distribution.

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 sample used; section 5 presents the results obtained; while the section 6 refers to the final remarks and finally the references used in this work.

Objective

The objective of this work is to propose a methodology for the construction of forecast models for returns of crude oil prices, 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.

The methodological approach used in this work in order to achieve this objective is described in section 3, as follows.

Methodological Approach—An Alternative Proposal

To reach 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 Mercantile Exchange (NYME) and in the London Market, respectively. These models consider the characteristics found in the financial assets return series: as the non-normality that generally happens and the heteroskedasticity of these return series. 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 WTI and the Brent types oil prices. The 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. Initially the heteroskedasticity of the returns was dealt with heteroskedasticity models, in which a variance law was based on the Autoregressive Conditional Heteroskedastic Model—ARCH Model presented in the econometric literature by Engle (1982). In 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:

$$\text{Model 1:}\quad \begin{aligned} &(R_t \mid I_{t-1}) \sim Student\ (\mu_t; \sigma_t^2, \nu) \\ &\mu_t = aR_{t-1} \\ &\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 \end{aligned}$$

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 at the time t;

σ_t = standard deviation of the returns at time t, and $e_t = (R_t - \mu_t)$.

The model 1 is constructed in two ways: 1(a), with intercept in the variance equation, and 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 used 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, at the same time t of the returns and with lag 1, or at time $t - 1$.

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 next, was constructed from a stochastic unit root model, the STUR model as suggested by Granger and Swanson (1977), to test the cointegration between crude oil prices and the exchange rate, respectively, the types of crude oil prices selected and the US$-Euro rate.

$$\text{Model 2:}\quad \begin{aligned} &R_{it} \sim Normal\,(\mu_{Rit}; \sigma_{Rit}^2; \nu_{Ri}) \\ &R_{it} = a_{it} + b_{it} ExchangeRate_{it} \\ &\sigma_{Rit}^2 \sim Gama \\ &\nu_{Ri} \sim Uniforme \\ &e_{it} = R_{it} - (a_{it} + b_{it} ExchangeRate_{it}) \end{aligned}$$

$$\begin{aligned} &e_{it} \sim Normal\ (\mu e_{it}, \sigma_i^2) \\ &\mu e_{it} = \rho_{it}\, \mu e_{it-1} \\ &\rho_{it} = \exp(\omega_{it}) \\ &\omega_{it} \sim Normal\ (\mu_{it}, \sigma_\omega^2) \\ &\mu_{it} = \mu_\omega + \varphi(\omega_{it-1} - \mu_\omega) \end{aligned}$$

For each *i* type oil, 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). In this way a series of the variable e_i is stationary. Therefore the returns of oil prices and the variation of the exchange rate are cointegrated.

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

$$\text{Model 3:}\quad \begin{aligned} & R_{it} \sim Student(\mu_{it};\sigma^2_{it};\nu_i) \\ & \mu_{it} = \alpha_{it} + \beta_{it} ExchangeRate_{t-1} \\ & \alpha_{it} \sim Student \\ & \beta_{it} \sim Student \\ & \sigma^2_{it} \sim Gama \\ & \nu_i \sim Uniforme \end{aligned}$$

For the determination of every posterior distribution of parameters, numeric methods based on Monte Carlo Markov Chain (MCMC) were used. The developed models were implemented in the BUGS (Bayesian Inference Using Gibbs Sampler) Software, in the WinBUGS 1.4 version, elaborated by Spiergelhalter, Thomas, and Best (2003), to obtain the posterior distribution using MCMC via Gibbs Sampling. The prior distributions used in all models were vague, 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 resort to 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, besides that the Mean Square Error (MSE) was calculated. The Deviance Information Criterion (DIC) proposed in Spiergelhalter, Best, Carlin, and Linde (2002) and implemented in the 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 determination of the posteriori of the interest parameters. Another selection model criterion used was the Root Mean Squared Error (RMSE).

For the implementation of the models the information used are described as follows.

The Data Used—The Sample

The information used for oil prices is the weekly prices collected on the Energy Information Administration (EIA), Official Energy Statistics from the U.S. government website. From these data the weekly returns, for each type of crude oil price, was calculated with the equation below 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 weekly time series of the exchange rate used here was collected from the European Central Bank web site. The weekly variation of the exchange rate was calculated in the same way of the oil price returns. All data was collected from January 2005 to March 2009.

Results

The posterior distributions were obtained from the implementation of previously introduced 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 prior distributions that is using high variances for the prior distributions of 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 above and the figures that follow show the results of model 1, an AR(1)-ARCH(1), that were estimated in two ways: the model 1(a) and the model 1(b). These models differ in variance equation, with and without intercept. Figure 1 and Figure 2 show plots with the oil weekly returns time series versus the returns forecasts obtained from model 1(a) for WTI and Brent types, respectively. The 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 had a MSE close to 0.0248, the Brent type 0.0309. Regarding the model 1(b), without intercept in the equation of the variance, the results reveal significant improvement regarding the model 1(a), as it can be observed in the plots in Figure 3 and Figure 4. For the model 1(b) the MSE is close to 0.0091 and 0.0041, for the WTI and Brent types, respectively.

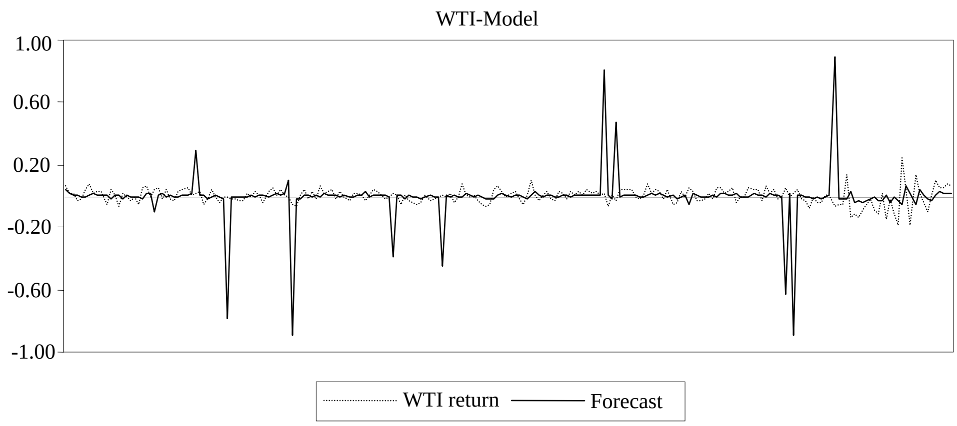

Figure 1. Results of model 1(a)—AR(1)-ARCH(1)—WTI return and forecast.

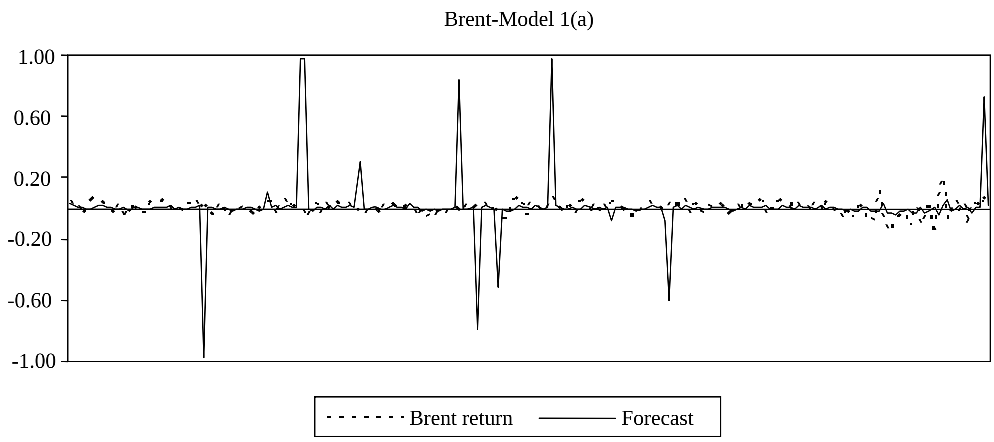

Figure 2. Results of model 1(a)—AR(1)-ARCH(1)—Brent return and forecast.

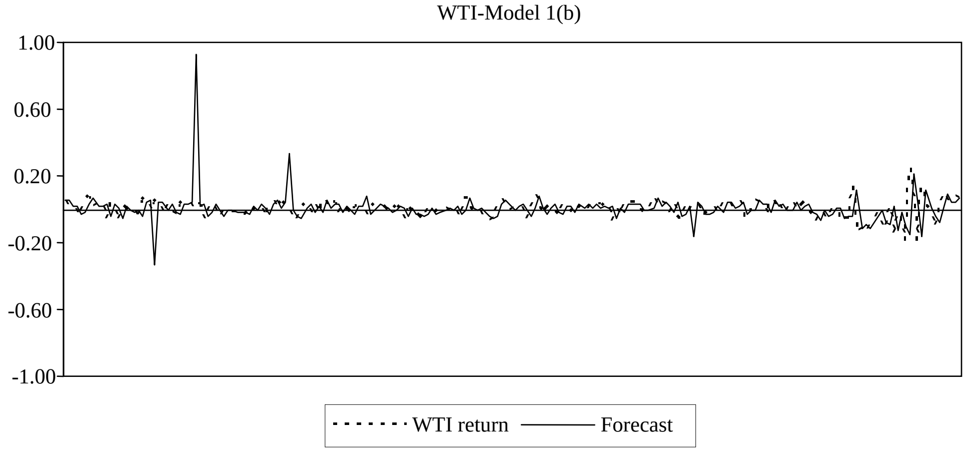

Figure 3. Results of model 1(b)—AR(1)-ARCH(1)—WTI return and forecast.

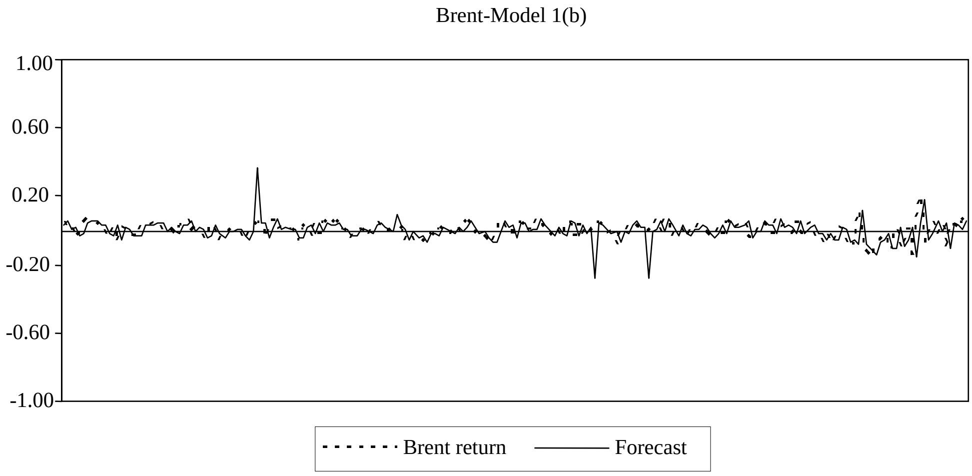

Figure 4. Results of model 1(b)—AR(1)-ARCH(1)—Brent return and forecast.

The results of the cointegration test applied to examine the long-run comovements between crude oil prices returns and the exchange rate are presented in the Tables 1 and 2 as follows. In these tables it's possible to see that 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.

Table 1

Results of Cointegration—Crude Oil Returns and Exchange Rate Variations

	WTI	Brent
mu.omega	0.000	0.000
	(0.000)	(0.001)
PR mean	0.4	0.5
Median	0.0	1.0
DIC	-572.72	-635.17

From Table 1 it's possible to infer that the average probability of the cointegration between weekly returns of crude oil prices and the variation of the exchange rate is 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. In the same table it must be highlighted the median of the cointegration probabilities obtained for the weekly oil prices of Brent type are the only indication of cointegration between the oil price returns and the variations of exchange rate. Thus it cannot be affirmed from this test that there is cointegration of these variables: oil prices returns and the exchange rate. Regarding the association of these two variables with product-moment correlation coefficient, a classical measure of association, shows that the returns series and the exchange rate are weakly associated, 0.27 and 0.32 for returns of WTI and Brent types respectively, with statistical significance.

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

	WTI	Brent
mu.omega	0.005	0.000
	(2.104)	(0.001)
PR mean	0.7	0.5
Median	1.0	1.0
DIC	768.12	289.72

Table 2 shows the results for inferences of the cointegration between the weekly oil prices series and the exchange rate, as well as these variables correlation. As shown in Table 1 and Table 2, the observations for the parameter mu.omega are the same or similar. The average probabilities of PR presented an indication of cointegration between oil prices of WTI type 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 oil prices of WTI and Brent types are 0.88 and 0.89 respectively, with statistical significance.

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 variable exchange rate is used as an independent variable in the same time of the return, as shown in the model. The MSE is close to 0.0169 and 0.0215 for the returns of the crude oil prices of WTI and Brent types, respectively. In this way this model presented a better performance than the model 1(a), but worse than the model 1(b).

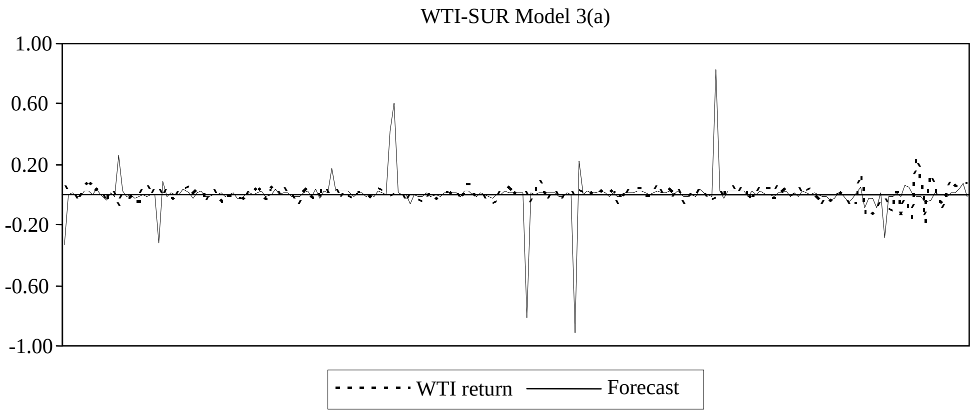

Figure 5. Results of SUR model 3(a)—WTI return and forecast.

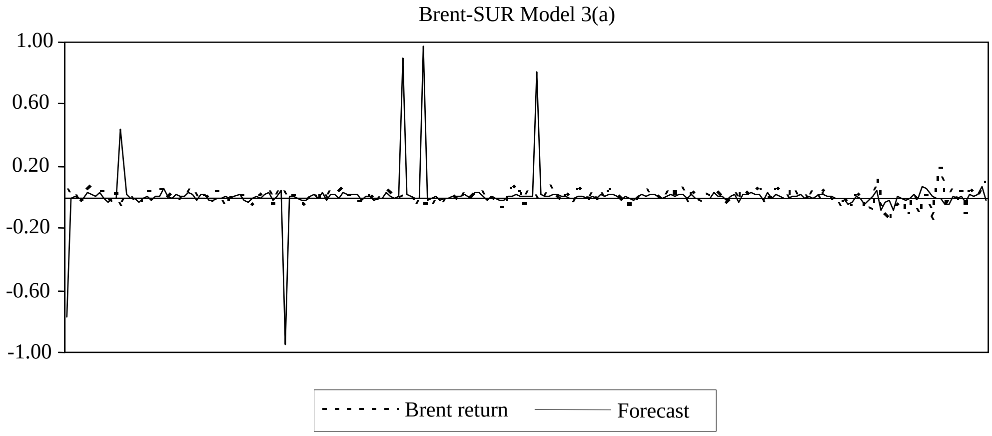

Figure 6. Results of SUR model 3(a)—Brent return and forecast.

In Figure 7 and Figure 8 the model 3(b) results are presented, that is, the results of model 3 using the exchange rate with lag 1 as an explanatory variable and the MSE performance indicator was 0.0268 and 0.0081 for the returns of oil barrel prices of types WTI and Brent, respectively. So when the explanatory variable changed, the MSE increased for returns of the WTI type and decreased for the Brent type.

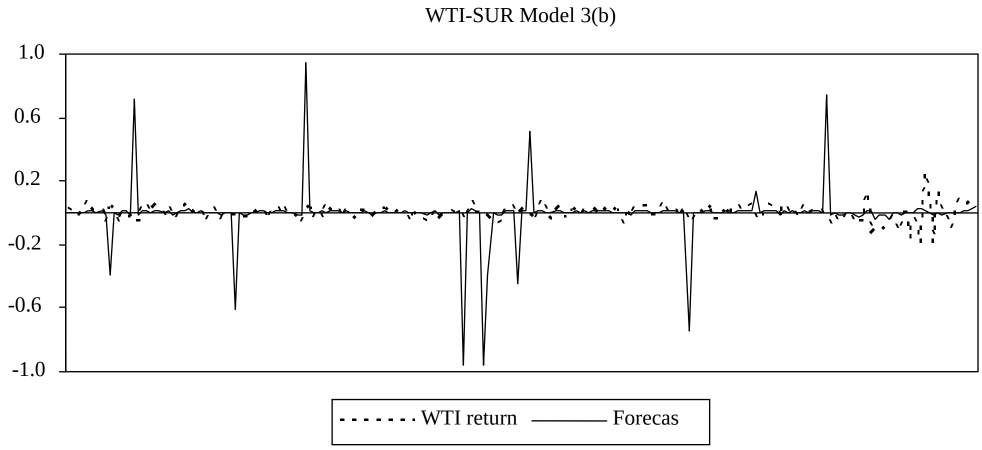

Figure 7. Results of SUR model 3(b)—WTI return and forecast.

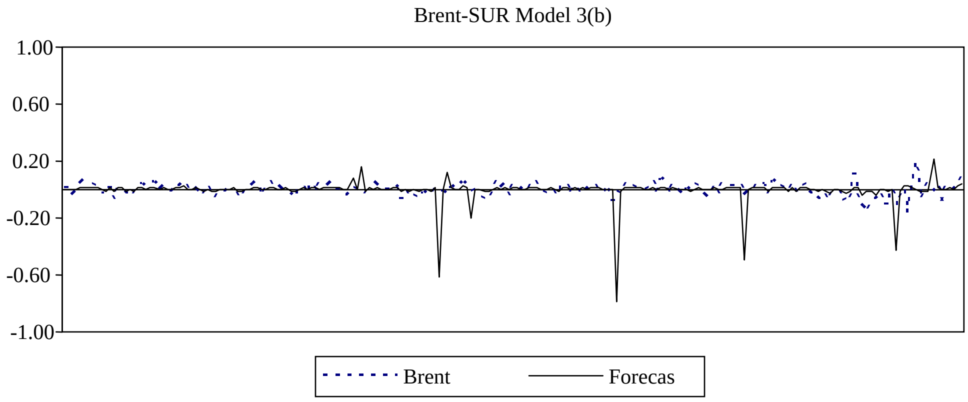

Figure 8. Results of SUR model 3(b)—Brent return and forecast.

Finally, Table 3 presents the summary of performance results of the models for forecast oil prices constructed 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).

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

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

Final Remarks

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

The results do not show the acceptance of cointegration hypothesis between oil prices, or returns, and exchange rate. It was observed that the exchange rate does not improve, nor turns the forecast models better. The best forecast performance was obtained with an autoregressive model. And the exchange rate does not improves, or turns better, the forecast models. With the presented models it is not possible to infer that the exchange rate is important to explain the oil barrel returns. The best forecast performance was obtained with an autoregressive model, that is, the best performance among these models was reach with a model that did not use the exchange rate as an explanatory variable.

This work hopes to make a contribution for the discussion of the theme that was dealt here. It is important to mention that the inferences can be enlarged with the utilization of other models, other methodologies or other samples. Given the relevance of the theme dealt here, oil price forecast, which is useful for those who participate directly in the market, that is, crude oil negotiators, or those who participate indirectly like firm and government planners, other researches should be conducted to contribute to the related areas literature like finance and energy economics.

References

Akgiray, V. (1989). Conditional heteroskedasticity in time series of stock returns: Evidence and forecasts. *Journal of Business, 62,* 55-80.

Chen, S., & Chen, H. (2007). Oil prices and real exchange rates. *Energy Economics, 29,* 390-404.

Congdon, P. (2001). *Bayesian statistical modeling*. New York, N.Y.: John Wiley & Sons.

Engle, R. (1982). Autoregressive conditional heteroskedasticity with estimates of United Kingdom inflations. *Econometrica, 50,* 987-1007.

Gelfand, A., & Ghosh, S. (1998). Model choice: A minimum posterior predictive loss approach. *Biometrika, 85*(1), 1-11.

Granger, C., & Swanson, N. (1977). An introduction to stochastic unit-root processes. *Journal of Econometrics, 80*(1), 35-62.

Migon, H., & Gamerman, D. (1999). *Statistical inference: An integrated approach*. New York, N.Y.: Arnold Publishers.

Panas, E., & Ninni, V. (2000). Are oil markets chaotic? A non-linear dynamic analysis. *Energy Economics, 22,* 549-568.

Sadorsky, P. (2000). The empirical relationship between energy futures prices and exchange rates. *Energy Economics, 22,* 235-266.

Salles, A. (2007). A Bayesian approach for the determination of the systematic risk in the international stock market. Proceedings of the 56th Session of the International Statistical Institute—ISI 2007.

Spiergelhalter, D., Best, N., Carlin, B., & Linde, A. (2002). Bayesian measures of model complexity and fit. *Journal of the Royal Statistical Society, B*(64), 583-639.

Spiergelhalter, D., Thomas, A., & Best, N. (2003). *User manual WinBUGS* (Version 1.3). MRC Biostatistics Unit, Institute of Public Health, Cambrige, UK.

Wang, S., Yu, L., & Lai, K. (2005). Crude oil price forecasting with TEI@I methodology. *Journal of Systems Science and Complexity, 18,* 145-166.

Xie, W., Yu, L., Xu, S., & Wang, S. (2006). A new method for crude oil price forecasting based on support vector machine. In V. N. Alexandrov, et al. (Eds.), *ICCS 2006*, Part IV, LNCS 3994, 444-454.