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Oil prices and the US effective exchange rate: A hidden cointegration analysis

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Abstract

We investigate the long-run relationship between the US Dollar effective exchange rate and oil prices (WTI) over the period from January 1986 to August 2014.We allow for the relationship to be asymmetric by employing the hidden cointegration technique of Granger and Yoon (2002) and Schorderet (2004). The Quandt – Andrews approach allows accounting for structural breaks. The results reveal an asymmetric long-run relationship between the two markets.

Keywords: exchange rate; oil prices; hidden cointegration; structural breaks; U.S.
JEL Classification Codes: C22, C5, F31, Q43

1. Introduction

Most of the early studies have established an adverse relationship between oil price changes and variations in main macroeconomic indicators such as GDP, CPI (For the effects of oil price changes to main macroeconomic indicators see Hamilton, 1983; Burbidge and Harrison, 1984; Hooker, 1996) and the unemployment rate (Loungani, 1986; Lee et.al, 1995; Papapetrou, 2001). Several explanations have been offered to interpret these empirical findings. Higher oil prices increase the cost of inputs in the production function and cause a reduction of the output that leads to slower economic growth. According to Bernanke (1983), the volatility of oil prices may cause a rise in uncertainty, leading to postponement of investments. Besides, uncertainty about oil prices may affect economic activity negatively (Elder and Serletis, 2010). Furthermore, increased oil prices may lead to a rise in the money demand (Bohi, 1989; Bernanke et.al, 1997). Brown and Yucel (2002) discuss the channels through which oil prices affect economic activity.

However, the relationship between exchange rates and oil prices has not been considered to such an extent. The link has been primarily studied by Golub (1983) and Krugman (1983a, b). Theoretically, several models have been developed in order to explain the determination of

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exchange rates. They are based on the interest rate parity, the monetary model, the purchasing power parity and the Taylor rule. Therefore, exchange rates are determined by differentials in interest rates, money supply, inflation and output based on the corresponding model specification. Presentation of the models can be found in Frankel and Rose (1995) and Rossi (2013).

Our purpose is to examine the possible dynamic linkages between oil prices and the US effective exchange rate accounting for possible non-linearities. Moreover, our data set, compared to previous research efforts, is extended and captures the recent financial crisis.

The outline of the paper is as follows. Section 2 reviews the literature. Section 3 presents the methodology and discusses the results. Finally, section 4 concludes.

2. Literature review

Benassy-Quere et al (2007), using a Vector Error Correction Model (VECM) approach found that rising oil prices lead to an appreciation of the US Dollar. Amano and Van Norden (1998) found a positive long-run relationship between the price of oil and the US exchange rates. Chen and Chen (2007) also found a positive and statistical significant long-run relationship between oil and exchange rates.

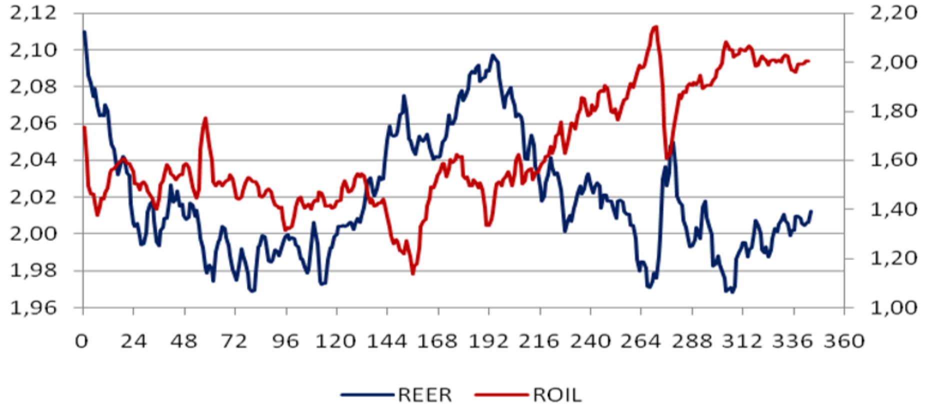
Using DOLS estimations Cheng (2008) found that oil price changes have a negative impact in both short and long-run horizon to US exchange rates. Narayan et. al (2008), using various GARCH models found that higher oil prices lead to a depreciation of the US Dollar exchange rate.

Since the linkages between the two variables remain controversial the existence of an asymmetric relationship between oil price changes and exchange rates has also been investigated. According to Enders and Dibooglu (2001), interventions by the monetary authorities may result in asymmetric adjustments in exchange rates. The reason is the different way the authorities may react to a currency appreciation than to a depreciation. Also, Ewing et. al (2006) suggests that asymmetries may be derived from heterogeneous expectations about nominal exchange rates, high transaction costs which restrain or decelerate the adjustment process, economic and political shocks which can affect oil prices and exchange rates differently and institution factors such as the decisions of the Organization of the Petroleum Exporting Countries (OPEC) about pricing and production policies.

Coleman et. al (2010), found evidence in favor of asymmetric cointegration between real exchange rates and real oil prices using a Smooth Transition Regression (STR) model. Ahmad and Hernandez (2013), investigated a group of major oil exporting and importing countries and applying the Threshold Autoregressive (TAR) and the Momentum Threshold Autoregressive (MTAR) models discovered asymmetry in the adjustment process. Akram (2004), evidenced the presence of non-linearities as he found that the effects on the Norwegian exchange rates of oil price changes vary depending on the level and trend of the latter prices. Buetzeret. al (2012), found that the response of exchange rates differs significantly depending on the source of the oil price shocks. Following Kilian's (2009) approach, they divided oil prices in different categories based on supply and demand side shocks.

To sum up, the linkages between the two variables are not quite explicit. We attempt to improve the understanding of this issue by adding new empirical evidence focusing on the detection of possible asymmetries and structural breaks.

Figure 1. Evolution over time of the REER and ROIL variables.



3. Data and empirical results

To investigate the relationship between oil prices and real exchange rates we employ the West Texas Intermediate (WTI) oil price index. Historical price data for WTI are taken from the Energy Information Administration. We also use the US Effective Exchange Rate (EER), a weighted average of the country's currency relative to an index or basket of other major currencies. The data are taken from the Federal Reserve Bank of St. Louis. The weights are determined by comparing the relative trade balances, in terms of one country's currency, with each other country within the index. Both variables are monthly, covering the period from 01/1986 to 08/2014 and all prices are real and in logarithmic form. The ROIL and REER denote the real West Texas Intermediate (WTI) oil prices and the real Effective Exchange Rates (EER) of the US Dollar respectively. Figure 1, shows the evolution over time of the two examined variables.

Table 1. Unit root tests results.

Levels		
	PP	KPSS
REER	-2.998	0.253 *
ROIL	-2.851	0.439 *
First differences		
	PP	KPSS
REER	-12.725 *	0.118
ROIL	-16.816 *	0.033

Notes
- PP is the Phillips Perron test and KPSS the Kwiatkowski-Phillips-Schmidt-Shin test.
-The model contains a constant and a deterministic trend.
-*, ** and *** denote statistical significance at the 1%, 5%, 10% level respectively.

At the first step, it is necessary to test for the integration properties of the series and thus we apply the Phillips and Perron (1988) unit root test (PP) and the Kwiatkowski et al. (1992) stationarity test (KPSS). The results, reported in Table 1, suggest that both variables are non-stationary in levels, while they turn stationary in first differences, at the 1% significance level.

In the next we apply three different cointegration methods. The conventional cointegration methods of Engle–Granger (1987) and Phillips–Ouliaris (1990), that are based on unit root tests of the residuals of the estimated models and the Johansen's (1991, 1995) Maximum Likelihood (ML) cointegration analysis, which provides two likelihood tests for the presence of cointegrating vectors, namely, the trace and the maximum eigen value tests. The estimation results, reported in Table 2, suggest the acceptance of the null hypothesis of no cointegration between the examined variables, at the 5% significance level for all tests employed.

Table 2. Cointegration tests results.

Dependent variable Exchange rates					
Engle Granger		Philips - Ouiliaris		Johansen	
t-statistic	Zt	t-statistic	Zt	Trace test	Max eigenvalue
-3.367176(α)	-16.575(α)	-3.367(α)	-16.575(α)	10.370(β)	8.296(β)

Notes:
-The critical values are calculated as described in MacKinnon et al. (1996).
- (α) indicates a model with constant and a deterministic trend.
- (β) indicates a model with a linear deterministic trend in the data and a constant in the CE
-*,** and *** denote statistical significance at the 1%,5%,10% level respectively.

Having failed to detect a long-run relationship between the examined series, we proceed by testing for the presence of possible structural breaks. Perron (1989) demonstrated that a break in the deterministic trend reduces the power of standard unit root tests dramatically.

Gregory et al. (1996) showed that the rejection frequency of the ADF test for cointegration falls substantially in the presence of a structural break in the cointegrating relation. We proceed by applying a residual-based cointegration test suggested by Gregory and Hansen (1996a, b), which permits the time of the structural change to be determined by the data, endogenously. We test three model specifications of structural change described as: (i) level shift, (ii) level shift with trend, and (iii) trend and regime shift where trend, level shift and slope coefficients can change. In particular, the tested models are presented below:

$$REER_t = \alpha_1 + \alpha_2 D_t + \gamma ROIL + \varepsilon_t \quad (1)$$

$$REER_t = \alpha_1 + \alpha_2 D_t + \beta trend_t + \gamma ROIL + \varepsilon_t \quad (2)$$

$$REER_t = \alpha_1 + \alpha_2 D_t + \beta_1 trend_t + \beta_2 trend_t D_t + \gamma_1 ROIL + \gamma_2 ROILD_t + \varepsilon_t \quad (3)$$

where D_t^τ is a dummy variable with $D_t^\tau = 0$ for $t < \tau$ and $D_t^\tau = 1$ for $t \geq \tau$ and τ the time of the structural break. The results, reported in Table 3, imply that we cannot reject the null hypothesis of no cointegration.

Table 3. Gregory Hansen Cointegration tests.

Panel A						
Depended Variables	Model Specification					
	Level break, no trend		Level break, trend		Regime and trend swift	
	t-statistic	Za	t-statistic	Za	t-statistic	Za
REER	-4.481	-41.203	-5.019	-42.659	-5.008	-38.059
Panel B						
T_b	Level break, no trend		Level break, trend		Regime and trend swift	
	10/1998	07/1999	04/1997	07/1999	11/1998	11/1998

Notes:
- t-statistic denotes the ADF minimum test statistic for a unit root across all possiblebreak points and Zt denotes the Philips – Perron unit root test respectively.
-The optimal lag length is determined by the Akaike Information Criterion.
- T_b denotes the time of the break.
-Critical values are tabulated in Gregory and Hansen (1996a, 1996b).
-*,** and *** denote statistical significance at the 1%,5%,10% level respectively.

Next, we adopt the hidden cointegration technique as developed by Granger and Yoon (2002) and Schorderet (2004)[1]. This approach allows us to relax the assumption of a common stochastic trend and test for possible different cointegration relationships[2] among positive and negative changes in exchange rates and oil prices.

Before we proceed, in Table 4 we present the results of the PP unit root and the KPSS stationarity tests for the negative and positive partial sums of the series. Actually the $REER^+$, $REER^-$, $ROIL^+$ and $ROIL^-$ denote the positive and negative partial sums of exchange rates and oil prices respectively. The results imply that all variables are non-stationary when tested in levels, at the 5% significance level, while in first difference form they become stationary. Hence, the decomposed variables are all integrated of order one I(1).

Table 4. Unit root tests of the decomposed series.

	PP	KPSS
Levels		
REER+	0.414	2.236*
REER-	-1.146	2.206*
ROIL+	0.262	2.222*
ROIL-	-0.914	2.230*
First differences		
	PP	KPSS
REER+	14.115*	0.080
REER-	-14.449 *	0.216
ROIL+	-12.763 *	0.170
ROIL-	-11.046 *	0.077

Notes:
-PP is the Phillips Perron test and KPSS the Kwiatkowski-Phillips-Schmidt-Shin test.
- The model contains a constant and without deterministic trend.
-*, ** and *** denote statistical significance at the 1%, 5%, 10% level respectively.

In the next step, we proceed with testing for possible hidden cointegration. The employed methodology allows us to search for a long–run relationship between the positive and negative components of the variables. In this direction we estimate the following equations.

$$REER_t^+ + \Delta REER_t^- = \alpha^+ + \beta^+ trend_t + \gamma^+ ROIL^+ + \varepsilon_{1t} \quad (4)$$

$$REER_t^+ + \Delta REER_t^- = \alpha^- + \beta^- trend_t + \gamma^- ROIL^- + \varepsilon_{2t} \quad (5)$$

$$REER_t^- + \Delta REER_t^+ = \alpha^+ + \beta^+ trend_t + \gamma^+ ROIL^+ + \varepsilon_{3t} \quad (6)$$

$$REER_t^- + \Delta REER_t^+ = \alpha^- + \beta^- trend_t + \gamma^- ROIL^- + \varepsilon_{4t} \quad (7)$$

[1]The method we used has been suggested by Schorderet (2004) to improve the hidden cointegration technique that has been originally proposed by Granger and Yoon (2002) and is justified by the nonlinear properties of partial sums of the series. According to Schorderet (2004) the OLS estimators although consistent, are likely to be biased in finite samples, therefore, he suggested the specification we used to overcome this problem.

[2]The cointegration models were developed by Engle and Granger (1987) but do not underline in all the cases the link between two, non-stationary time series. Thus, the asymmetric cointegration models emerged. The hidden cointegration represents a particular case of asymmetric cointegration and shows that we may observe common dynamics of time series, in their positive and/or negative components. It allows for distinct cointegration relationships between subcomponents of time series, even when cointegration between them is not identified (Honarvar, 2009). Therefore, we use the hidden cointegration approach as developed by Granger and Yoon (2002) and Schorderet (2004).

Table 5. Hidden Cointegration.

Panel A		
	Model specification 1	
	$REER_t^{+} + \Delta REER_t^{-} = \alpha^{+} + \beta^{+} trend_t + \gamma^{+} ROIL^{+} + \varepsilon_t$	
Variable	Coefficient	t-Statistic
$ROIL^{+}$	-0.003	-0.725
α^{+}	-0.025*	-14.366
$trend_t$	0.002*	37.929
	Residual based Cointegration tests	
Engle - Granger		Phillips – Ouliaris
-4.561 ($^{\beta}$)*		-4.581 ($^{\beta}$)*
	Quandt – Andrews stability test	
Max LR F-stat (10/2008)	85.125	0.000
Max Walt F-stat (10/2008)	255.375	0.000
Panel B		
	Model specification 2	
	$REER_t^{+} + \Delta REER_t^{-} = \alpha^{-} + \beta^{-} trend_t + \gamma^{-} ROIL^{-} + \varepsilon_t$	
Variable	Coefficient	t-Statistic
$ROIL^{-}$	-0.064*	-8.205
α^{-}	-0.035*	-19.057
$trend_t$	0.001*	16.181
	Residual based Cointegration tests	
Engle – Granger	Phillips – Ouliaris	
-5.089 ($^{\beta}$)*	-4.964 ($^{\beta}$)*	
	Quandt – Andrews stability test	
Max LR F-stat (09/2006)	73.006	0.000
Max Walt F-stat (09/2006)	219.018	0.000
Panel C		
	Model specification 3	
	$REER_t^{-} + \Delta REER_t^{+} = \alpha^{+} + \beta^{+} trend_t + \gamma^{+} ROIL^{+} + \varepsilon_t$	
Variable	Coefficient	t-Statistic
$ROIL^{+}$	-0.089*	-11.251
α^{+}	-0.080*	-25.571
$trend_t$	-0.001*	-9.823
	Residual based Cointegration tests	
Engle – Granger	Phillips – Ouliaris	
-2.800 ($^{\beta}$)	-3.028 ($^{\beta}$)	
	Quandt – Andrews stability test	
Max LR F-stat (04/1999)	176.682	0.000
Max Walt F-stat (04/1999)	530.046	0.000
Panel D		
	Model specification 4	
	$REER_t^{-} + \Delta REER_t^{+} = \alpha^{-} + \beta^{-} trend_t + \gamma^{-} ROIL^{-} + \varepsilon_t$	
Variable	Coefficient	t-Statistic
$ROIL^{-}$	0.067*	3.807
α^{-}	-0.047*	-11.344
$trend_t$	-0.001*	-7.157

	Residual based Cointegration tests	
Engle – Granger	Phillips – Ouliaris	
-2.264 (β)	-2.138 (β)	
	Quandt – Andrews stability test	
Max LR F-stat (01/1998)	180.683	0.000
Max Walt F-stat (01/1998)	542.051	0.000

Notes:
-The critical values are calculated using the approach as described in MacKinnon et al. (1996).
-(α) indicates a model with constant and without deterministic trend, (β)a model with constant and deterministic trend.
- *,** and *** denote statistical significance at the 1%,5%,10% level respectively.

Following Engle – Granger (1987) and Phillips – Ouliaris (1990), we test the null hypothesis of no cointegration against the alternative of cointegration based on the stationarity of the residuals of the above equations (4-7). The results, presented in tables 5, reveal evidence of hidden cointegration in two cases: In particular, between positive oil price changes and positive exchange rate changes as well as between negative oil price changes and positive exchange rate changes (models 1 and 2).

The adoption of the above long-run estimates assumes their stability over the examined time period, so we further employ the Quandt-Andrews breakpoint test. The test was originally introduced by Quandt (1960) and later developed by Andrews (1993) and Andrews and Ploberger (1994). The Quandt–Andrews breakpoint test is based on a single Chow breakpoint test that is employed on every observation between two dates. The corresponding F-statistics are then summarized into one statistic for a test with null hypothesis that of no breakpoint. In every single Chow test, two statistics are used: the Likelihood Ratio F-statistic and the Walt F-statistic. Then, the Maximum statistic, the Average and the Exponential transformation of the individual Chow tests are calculated.

The results of the Quandt–Andrews breakpoint test, reported in Table 5, imply that the relationship between oil and exchange rate components, as described in equations (4-7), is not stable, and that a structural break may exist in all cases.

Therefore, once again, we apply the hidden cointegration technique by taking under consideration the structural breaks detected by the Quandt–Andrews test.

The results, reported in table 6, imply the existence of hidden cointegration in three cases (models 1, 2 and 3). Positive oil prices changes affect exchange rates negatively (Panels 1 and 3) while negative oil price changes have a positive effect on exchange rates (Panel 2) in the long-run time horizon. However, we failed to detect a long-run relationship between negative oil price changes and negative exchange rates changes (Panel 4). Regarding the long-run coefficients we found that negative oil price changes have a greater impact (γ^{+}= 0.068) on increased exchange rates than that of positive oil price changes (γ^{-}= - 0.039) implying the presence of asymmetry in the effects of oil price changes on the exchange rates.

Summing up, the results imply that positive oil price changes have a negative impact in the US exchange rates; in other words, increased oil prices lead to a depreciation of the US Dollar in the long run. On the other hand, negative oil price changes seem to have a long-run relationship only with the positive exchange rate changes. The differences in the estimated cointegration vectors between the positive and negative components imply asymmetry. These results indicate that the US economy is depending on imports more than its major trading partners and therefore increased oil prices may lead to a deterioration of the US current account. Therefore, the US Dollar depreciates in absolute terms more than the currencies of its major trading partners. The presence of asymmetry can be explained by several sources, such as monetary policy, but further research is needed. However, we cannot eliminate the possibility that what we observe is a result of a portfolio re-balancing mechanism as investors, in order to limit their exchange rate exposure, try to manage their risk (Hau and Rey, 2004).

Table 6. Hidden Cointegration.

Panel A

Model specification 1

$$REER_t^{+} + \Delta REER_t^{-} = \alpha_1^{+} + \alpha_2^{+} D_t + \beta^{+} trend_t + \gamma^{+} ROIL^{+} + \varepsilon_t$$

Variable	Coefficient	t-Statistic
$ROIL^{+}$	-0.039*	-9.451
α_1^{+}	-0.023*	-17.608
D_t (10/2008)	0.034*	15.371
$trend_t$	0.002*	50.702

Residual based Cointegration tests

Engle – Granger	Phillips –Ouliaris
-5.671 ($^{\beta}$)*	-5.494 ($^{\beta}$)*

Panel B

Model specification 2

$$REER_t^{+} + \Delta REER_t^{-} = \alpha_1^{-} + \alpha_2^{-} D_t + \beta^{-} trend_t + \gamma^{-} ROIL^{-} + \varepsilon_t$$

Variable	Coefficient	t-Statistic
$ROIL^{-}$	-0.068*	-8.623
α_1^{-}	-0.038*	-18.057
D_t (09/2006)	-0.005*	-2.577
$trend_t$	0.001*	15.887

Residual based Cointegration tests

Engle - Granger	Phillips –Ouliaris
-5.212 ($^{\beta}$)*	-5.083 ($^{\beta}$)*

Panel C

Model specification 3

$$REER_t^{-} + \Delta REER_t^{+} = \alpha_1^{+} + \alpha_2^{+} D_t + \beta^{+} trend_t + \gamma^{+} ROIL^{+} + \varepsilon_t$$

Variable	Coefficient	t-Statistic
$ROIL^{+}$	-0.069*	-11.930
α_1^{+}	-0.077*	-33.801
D_t (04/1999)	0.037*	17.974
$trend_t$	-0.001*	-17.688

Residual based Cointegration tests

Engle - Granger	Phillips –Ouliaris
-4.317 ($^{\beta}$)**	-4.176 ($^{\beta3}$)**

Panel D

Model specification 4

$$REER_t^{-} + \Delta REER_t^{+} = \alpha_1^{-} + \alpha_2^{-} D_t + \beta^{-} trend_t + \gamma^{-} ROIL^{-} + \varepsilon_t$$

Variable	Coefficient	t-Statistic
$ROIL^{-}$	0.075*	6.603
α_1^{-}	-0.050*	-18.362
D_t (01/1998)	0.045*	21.731

$trend_t$	-0.001*	-11.001
	Residual based Cointegration tests	
Engle - Granger	Phillips - Ouliaris	
-3.851 ($^{\beta}$)	-3.792 ($^{\beta}$)	

Notes:
-The critical values are calculated using the approach as described in MacKinnon et al. (1996).
-($^{\alpha}$) indicates a model with constant and without deterministic trend, ($^{\beta}$)a model with constant and deterministic trend.
- *,** and *** denote statistical significance at the 1%,5%,10% level respectively.

4. Conclusions

In this paper we investigated the links between oil prices and exchange rates. For this purpose in the first step we employed the Engle-Granger (1987), Phillips-Ouiliaris (1990) and Johansen (1991, 1995) cointegration technique. The results from all methods indicated that there is no long-run relationship between the investigated markets.Furthermore, using the Gregory and Hansen (1996a, b) approach to account for structural breaks, we confirmed the previous results. However, using the hidden cointegration method of Granger and Yoon (2002) and Schorderet (2004), we found evidence of hidden cointegration. Nevertheless, the Quandt–Andrews break point test revealed that the relationship between the positive and negative oil prices and exchange rate components are not stable and a possible structural break in all equations exists. When the structural breaks were incorporated in the model we found new evidence in favor of hidden cointegration implying that structural breaks should not be ignored. We found that the effects of increased oil prices in exchange rates differ from that of decreased oil prices and confirm that oil price change is a source of asymmetry. The results revealed the existence of three cointegration relationships. In particular we found that increased oil prices affect exchange rates negatively while decreased oil prices have a positive impact in exchange rates. The effects differ among them in size and reveal the presence of asymmetries. Our findings could be important for the understanding of the relationship between oil and exchange rates and could be useful to investors and other market participants, such as financial managers, analysts and firms, in order to manage their investments and minimize their portfolio risks.

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