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OIL PRICE AND THE DOLLAR

VIRGINIE COUDERT, VALÉRIE MIGNON, & ALEXIS PENOT

ABSTRACT

The aim of this paper is to test whether there is a stable long-term relationship between oil prices and the U.S. effective exchange rate, expressed in real terms. To this end, we perform co-integration and causality tests between the two variables. Our results show that causality runs from oil prices to the exchange rate. Moreover, as we investigate the channels through which oil prices affect the dollar exchange rate, we find out that the link between the two variables is transmitted through the U.S. net foreign asset position.

Keywords:
oil prices, effective exchange rate, net foreign asset position, co-integration, causality, error correction model.

JEL Classification: C22, E32, Q43.

Corresponding author: ***Valérie Mignon****, University of Paris 10, EconomiX-CNRS, and CEPII, Paris, France. Phone: 33 1 40 97 58 60.*
Email: Valerie.Mignon@u-paris10.fr.
Virginie Coudert*, Banque de France.*
Email: virginie.coudert@banque-france.fr
Alexis Penot*, GATE, University of Lyon, CNRS, ENS-LSH, Centre Léon Bérard, France.*
Email: penot@gate.cnrs.fr

1. INTRODUCTION

Both oil price and the U.S. dollar exchange rate are leading economic variables, which drive the evolution of the world economy. Their changes deeply affect international trade and economic activity in all countries. An important issue is therefore the link between these two key variables: are they moving independently or not? What are the empirical evidences on the statistical link between them? Are there theoretical grounds that could explain the channels of transmission?

Several previous studies have already tackled related issues. On the one hand, empirical works by Throop (1993), Zhou (1995), Amano and van Norden (1995), Dibooglu (1995) have evidenced a relation between oil prices and exchange rate movements. In the case of the dollar, the link is generally found to be positive, which means that an increase in oil price goes with a dollar appreciation. Very few of these papers then try to ask which variable causes the other. That is the case for Amano and van Norden (1995), who show that oil price is a main driving factor of the long-term evolution of exchange rates in Germany, Japan and the United States (see also Bénassy-Quéré *et al.*, 2007). On the other hand, there are also some theoretical models, aiming at describing the interactions between oil price and the U.S. dollar exchange rate such as the ones by Krugman (1983a,1983b), McGuirk (1983), Golub (1983) and Rogoff (1991).

In this paper, we start by surveying all theoretical reasons that could explain the relationship between oil prices and the U.S. dollar exchange rate. Firstly, as oil trade is denominated in U.S. dollars, movements in the dollar effective exchange rate affect the price of oil as perceived by all countries outside the United States. Therefore, a change in the dollar exchange rate can trigger changes in oil demand and supply, and eventually changes in the oil price itself. Secondly, the reverse causality can also be found, as changes in oil prices may well affect the effective exchange rate of the dollar. The reason can be found in the literature on equilibrium exchange rates. In the model by Faruqee (1995), if a country accumulates foreign assets, its exchange rate appreciates, and this movement occurs without impeding its current account balance. This is because capital income takes over the loss in trade receipts induced by the deteriorated competitiveness. As a change in oil price affects all the world imbalances, the induced change in international assets may have an impact on the exchange rates. Thirdly, we take stock of portfolio models, especially the ones by Krugman (1983a) and Golub (1983), which were designed to take into account trade and financial interactions between the United States, oil producer countries and third countries.

This exhaustive survey of theoretical interactions between the two variables paves the way for every possible link between the two variables: either positive, negative and in both directions of causality. If there are some theoretical reasons for every kind of link, one of them has to be stronger than the others. Therefore, the question is to disentangle the alternative theoretical explanations by confronting them to the data.

We therefore perform an empirical study of the relation between oil prices and the dollar real effective exchange rate over the period spanning from 1974 to 2004. We focus on finding out a long-term relationship between these two variables. We also check the direction of causality. Our results show that the relation is positive, running from the oil price to the U.S. dollar. Among the possible explanations reviewed, the one involving the equilibrium exchange rates theory is the only one to fit the found relationship. We make further tests, in order to check it. We evidence that U.S. foreign assets are at stake in the channel of transmission from the oil price to the dollar exchange rate.

Section 2 provides a thorough survey of all possible explanations for the existence of a relationship between oil price and the dollar exchange rate. Two possible causality directions and all kind of interactions are examined. Section 3 presents the econometric study of the relationship between the two variables. The last section concludes.

2. THEORETICAL INTERACTIONS BETWEEN THE DOLLAR EXCHANGE RATE AND OIL PRICE

The possible existence of a long-term relationship between oil prices and the dollar effective exchange rate implies a causality between the two variables. Previous studies show a causality direction from oil prices to the dollar (see Amano and van Norden (1995) and Bénassy-Quéré *et al.* (2007) among others). However, there are some arguments that also may justify the other direction of causality. We successively study the two types of causality and try to assess the resulting sign of the relationship in each case. Then we turn to some portfolio models.

2.1 Impact of the dollar exchange rate on oil demand and supply

The dollar effective exchange rate has an impact on the oil demand and supply since it affects the price of oil, as it is perceived by all consumers and producers outside the U.S. This effect depends on the currencies used in the different transactions linked to oil activities.

Effects on demand. Oil purchases are paid in dollars. However, demand depends on the domestic price for consumer countries which generally changes with the dollar fluctuations. Thus, the dollar depreciation reduces the oil price in domestic currencies for countries with a floating currency, like the euro zone or Japan. The effect is neutral for countries that have a currency pegged to the dollar, like China. On average, everything else being equal, a dollar depreciation generally tends to decrease the oil price in consumer countries. This leads to an increase in their real income and an increase in their oil demand[1]. Therefore, the dollar depreciation *a priori* has a positive impact on oil demand and should contribute to raise the price.

Effects on supply. Oil companies use domestic currencies of producer countries to pay their employees, taxes and other costs. These currencies are often linked to the dollar, because of fixed-exchange rate regimes adopted by most producer countries (Frankel, 2003). Thus, dollar changes probably affect the price as perceived by the producers less than the one perceived by demanders.

Drilling activities are linked to oil prices: when this price increases, some hard-to-exploit wells, considered as non profitable so far, become profitable and the production capacity increases. Empirical studies have validated this positive link between the two variables in North America, Latin America and Middle East. However, this does not seem true for the European and African countries. Noticeably, the relationship between oil price in dollars and

[1] It is the same for the United States. The dollar depreciation cuts the purchasing power of U.S. households but the income elasticity of oil demand is probably weak. Moreover, the dollar depreciation raises the external demand, generating a higher oil demand.

drilling activities has changed since 1999. Nevertheless, it is difficult to determine whether this change comes from the drop in oil price in 1998 and early 1999, or from the introduction of the euro as a competitive currency in 1999.

A dollar depreciation can also trigger inflation and reduce the income in oil producer countries, the currencies of which are linked to the dollar. All countries are not affected in the same way: OPEC that imports a lot from the United States is less affected than countries that import more from Europe or Asia. The increase in inflation and the decrease in purchasing power reduce the real disposable income and therefore the income available for drilling, everything else equals. Overall, a dollar depreciation may result in a reduction in oil supply.

Effects on the short and long run. On the short run, the supply is weakly elastic to price both upwards and downwards. The upward flexibility is weak because of the production capacity constraints. The downward flexibility is also small because the marginal production cost is generally rather low, inferior to the sale price, which urges producers not to limit their production when prices decrease. On the short run, the demand is also rather inelastic to prices. As rightly underlined by Carnot and Hagege (2004), this can be explained by the lack of substitutes to oil that could be quickly and easily exploited at a low cost. In sum, on the short run, supply and demand are quite inelastic.

The effects of oil prices on supply and demand are mainly observable on the long run. At this horizon, the supply is flexible because it is possible to implement new investments to raise the production capacities. The demand also becomes more elastic because other sources of energy can be developed to replace oil. In sum, as underlined by Carnot and Hagege (2004), "everything happens as if expectations were self-fulfilling on the short run (the expectation of a price increase urges buyers to purchase, which increases spot prices) but counter-fulfilling in the long run: the expectation of durably higher prices can give rise to mechanisms that are able to reduce price on the long run. Thus, market mechanisms act as a driving force that generally prevents price from getting too far away from a range of possible equilibrium prices."

Consequences on the relationship. Overall, a dollar effective depreciation causes an increase in oil demand and a reduction in supply, mainly on the long run, which tends to boost oil price. The early 2000s period is a good illustration of this mechanism. As underlined by Carnot and Hagege (2004), the increase in oil prices stems from two simultaneous factors: on the one hand, the strong surge -- badly anticipated -- of oil demand, particularly in the United States and in China; on the other hand, dwindling investments in the oil sector that led to a stagnation of production capacities. In this context, the tensions on supply have provoked fears of shortage[2].

However, if those demand and supply effects can correctly explain the situation of the early 2000s, they are unable to account for the relationship found in empirical studies since it has the opposite sign: a dollar depreciation is associated to a drop in oil price, not a raise.

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[2] Noticeably, the strong concentration of production capacities, mainly in Saudi Arabia, limits the market mechanisms, especially during periods characterized by strong tensions on capacities.

2.2 Impact of oil price on the dollar effective exchange rate

There are also some reasons to believe that oil price could affect exchange rates, and the dollar in particular. A frequently given explanation is the preference of oil exporting countries for financial investments in dollars (Amano and van Norden, 1993, 1995). In this framework, a surge in oil prices boosts producer countries' wealth, and also demand for dollar assets.

Another explanation can be found in reduced-form exchange rate models, such as Faruqee (1995) or more generally in the BEER (Behavioural Equilibrium Exchange Rate) models, pioneered by Clark and McDonald (1998). In this approach, two independent variables are frequently used for explaining the exchange rate: the terms of trade and net foreign assets. Now, oil prices certainly have an influence on these two variables, which would therefore justify their impact on the exchange rate.

A first quick reasoning leads to a negative relation between oil price and the dollar exchange rate. Indeed, an increase in oil price should deteriorate the U.S. terms of trade and then lead to a dollar depreciation. Moreover, that increase would have the same effect on the U.S. current-account deficit, which should widen, leading to a reduction in the U.S. net foreign assets (even if the incomes from oil are recycled in dollars). The dollar depreciation is then required to stabilize the U.S. external position. However, the previous reasoning is not complete since it overlooks the multilateral nature of exchange rates. A more complete reasoning would allow explaining the positive relationship usually found in the literature by taking into account the relative effect on the United States compared to its trade partners. If the United States is an important oil importer, an oil price increase can deteriorate its situation; however, if it imports less than other main countries, such as the euro area or Japan, its relative situation may well improve compared to other countries. Thus, an oil price increase would lead to a dollar appreciation relative to the euro and the yen, and eventually to a dollar appreciation in effective terms.

2.3 Interactions in a portfolio model

Other explanations are provided through the works by Krugman (1983a, 1983b) and Golub (1983), who have developed models to describe the links between oil price and the dollar exchange rate. Golub (1983) assumes that the world is divided in three areas: OPEC, the United States and the European Union. His model studies the effects of wealth transfers that follow an oil price increase and their impact on portfolio equilibria[3]. Thus, an oil price increase will cause a dollar depreciation relatively to the euro if OPEC propensity to hold euros is relatively high. Therefore, the impact on exchange rate depends on the fact that the wealth reallocation due to the oil price increase is the outcome of an excess demand for European currencies (it means an excess supply of dollars). In this case, the European currencies will appreciate relatively to the dollar, raising their share in the global wealth and thus restoring the portfolio equilibrium.

In a related approach, Krugman (1983a) uses a dynamic partial equilibrium framework to model how producer countries use the revenue of their oil exports in dollars. By demanding more or less dollars, they will affect *in fine* the dollar exchange rate. The model also consists in

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[3] Thus, this is a model of portfolio choice in which the currencies (the euro and the U.S. dollar) are financial assets.

three areas: the United States, Germany — standing for the whole European Union — and OPEC. The first two sell goods and services to themselves and to OPEC which only sells oil at a price that is assumed exogenously fixed in dollars. Then, OPEC distributes its purchases in the two other countries with a proportion γ which is a function of the dollar/mark exchange rate:

$$X_G = \gamma(V)X$$

where X is the imports to OPEC. Those that are noted X_G come from Germany and V is the exchange rate between the U.S. and the German currencies.

The crucial assumption made by Krugman is that OPEC spending adjusts only gradually to the level of its exports income:

$$\dot{X} = \lambda(P_O\overline{O} - X)$$

where $\overline{O}$ represents the total exports made by OPEC, P_O being their price. In other words, if oil price increases, OPEC will not immediately use all this new income in extra imports.

This model has only two assets: dollars and marks. OPEC shares its wealth between the two, according to a proportion α :

$$D_O = (1-\alpha)W_O$$

where D_O represents the assets in dollars held by OPEC and W_O its total wealth.

The relationship between the exchange rate V and OPEC's spending in German and U.S. goods depends both on α and γ. The intuition is the following: an increase in OPEC's spending in German and U.S. goods beyond their long-term levels will have two effects on the German balance of payments: the current account will benefit from the extra German exports but the capital account will suffer from the fact that OPEC will sell some of its marks to finance this new consumption. It is therefore very difficult to *a priori* determine a clear relationship between OPEC's spendings and the exchange rate change.

Krugman extends this analysis to an increase in oil price that triggers at least on the short run, an increase in income for OPEC. Then, a third parameter becomes essential, σ, that measures the German share in worldwide oil imports. The short-run impact depends on how large α is compared to σ while the long-term effect depends on the comparison between γ and σ.

Let's use another intuitive description of these mechanisms: since OPEC spends its extra exports income only after a lag, an increase in oil price does not immediately lead to an increase in exports for industrial countries. This will deteriorate their current account but, conversely, their capital accounts will improve since OPEC invests its surpluses in dollars and marks. The sign of the effect on the dollar exchange rate is determined by the comparison between the proportion invested in dollars by OPEC and the share of the United States in the current account deficit of the industrialized world.

However, after a lag, OPEC will start to spend its surpluses in new imports and will therefore reduce its accumulation of foreign assets. The German and U.S. balances of payments will no longer be mainly determined by the OPEC's preferences in financial investments but by its preferences in consumption goods. On the long run, only these latter will matter to know the final direction of exchange rate variations. Analytically, the equilibrium condition on the long run is described by:

$$\frac{\partial(\dot{V}/V)}{\partial P_O} = \frac{\overline{O}(\sigma-\alpha)}{M_{US}/V + \alpha(1-\alpha)W_O + D_G}$$

where M_{US} represents the marks held by Americans and D_G the dollars held by Germans. On the long run, the equilibrium becomes:

$$\frac{\partial V}{\partial P_O} = \frac{\overline{O}(\sigma-\gamma)}{\frac{\partial T}{\partial V} + X\frac{\partial \gamma}{\partial V}}$$

where T stands for the German trade balance, relatively to the U.S.

The interesting result of these conditions is that, in some configurations, the initial change in the exchange rate can be different from the long-term trend. For example, it will be the case if OPEC prefers U.S. investments but German goods. Thus, depending on whether OPEC accumulates a lot of assets in the United States or imports a lot of goods from Europe, the final outcome on the dollar exchange rate will be very different.

Such models show that one has to distinguish short-run impacts (where the financial approach is more relevant) and long-run impacts where the real approach is more appropriate. On the short run, the impact of an oil price increase depends on the U.S. weight in the global oil imports compared to their weight in the assets held by OPEC. On the long run, the effect depends on the weight of oil in the U.S. total imports compared to the U.S. weight in OPEC's imports. Empirically, it is possible that the two effects play in the opposite direction: on the short run, an oil price increase would tend to push the dollar up while, on the long run, a depreciation could happen.

3. EMPIRICAL STUDY OF THE RELATION BETWEEN THE DOLLAR REAL EFFECTIVE EXCHANGE RATE AND THE REAL OIL PRICE

Our empirical analysis is based on monthly data of oil prices and dollar exchange rates from January 1974 to November 2004[4]. Data are extracted from the *Datastream* database. The oil price variable[5] is expressed in real terms, i.e. deflated by the U.S. consumer price index. The exchange rate is the dollar real effective exchange rate[6].

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4 Note that the period starts in 1974 since this date corresponds to the beginning of the floating exchange rate period, avoiding the turbulences linked to the 1973 transition year.

5 Market price crude petroleum.

6 The dollar real effective exchange rate is calculated as the trade-weighted average of bilateral real exchange rates of the USD against trade partners. The detail of this variable and its methodology are indicated in the OECD's Main Economic Indicators.

3.1 Preliminary study of variables

Figure 1:
Real effective exchange rate of the dollar (left axis) and real oil price (right axis) in logarithm.

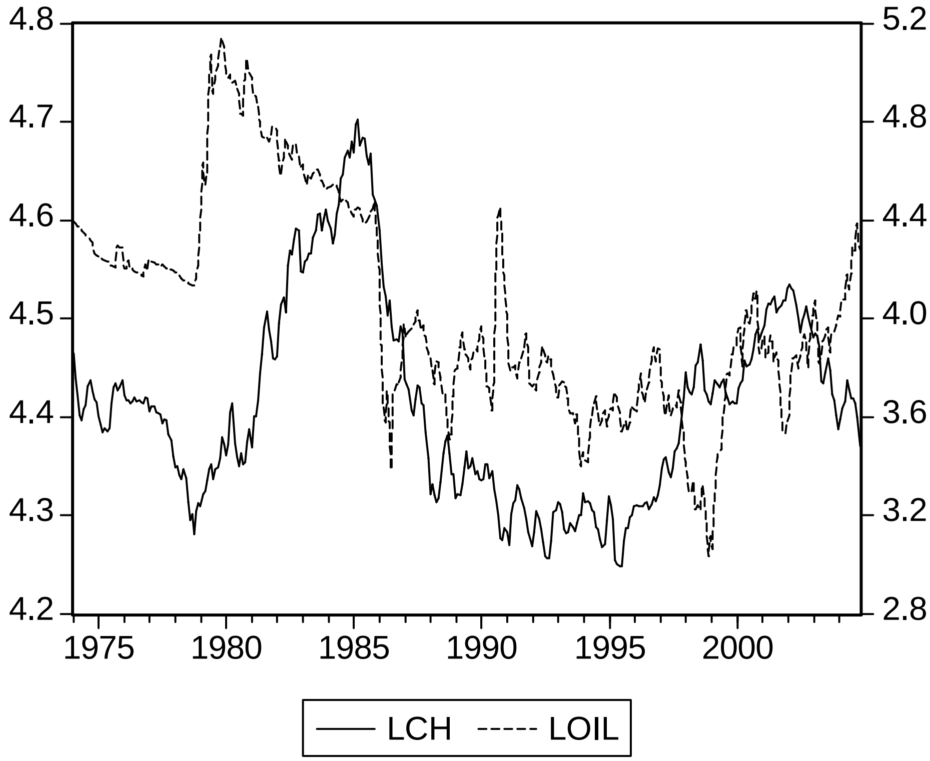

Figure 1 reports the dollar effective exchange rate[7] (*LCH*) and oil prices (*LOIL*) in real terms. Both series are taken in logarithms. Several observations can be made. First, it seems that both variables have similar evolutions when average fluctuations are low. For example, the 1986-1997 period appears to be characterized by a positive and relatively stable relation between the two variables. When exchange rates movements are more pronounced, the direction of the relation seems to be inverted. Thus, the early 1980s strong increase in the dollar was associated to a decrease in oil prices. The conclusions would be similar for the recent periods of dollar appreciation: 1997-1999 and early 2000s. The direction of the relationship between the two variables is not clear cut and seems to depend on the considered period[8]. Secondly, the oil variable seems to "lead" the exchange rate variable. In other words, if the causality between the two variables exists, it seems to run from the oil price to the

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7 An increase indicates an appreciation of the dollar.

8 These remarks raise some questions about the more or less speculative nature of the times during which this positive relationship does not seem to hold. Figures A1 and A2 in the appendix report the volatilities of the two variables. The early 1980's and the 1997-1999 period are indeed characterized by a strong exchange rate volatility but this is not true for the early 2000s.

exchange rate. Thus, the speculation on oil would lead to a speculation on the dollar, while the opposite does not seem to hold.

We try to check these intuitions through an empirical analysis. The first mandatory step is the study of stationarity: the results are reported in table A1 in the appendix with Augmented-Dickey-Fuller (ADF) and Phillips-Perron (PP) tests applied to the two variables[9]. It turns out that both series are integrated of order one. The descriptive statistics included in table A2 indicate that both series have an excess kurtosis, which is particularly strong for oil price, giving evidence of a high probability of extreme points. Besides, both series have an asymmetric distribution (skewed to the right for oil price changes and to the left for exchange rates changes).

3.2 Is there a stable equilibrium relation between the two series?

In order to evaluate a stable long-term relation between oil prices and the real effective exchange rate of the dollar, we study the co-integration between the two variables[10]. To this end, we apply the procedure developed by Johansen (1988) and Johansen and Juselius (1990). The results of the trace test proposed by Johansen and Juselius (1990) are reported in table 1[11].

Table 1: Co-integration test

Null hypothesis	Trace statistic	p-value
No relation	15.98*	0.04
At most one relation	3.61	0.06

*: rejection of the null hypothesis at the 5% significance level.

According to the trace test, the null hypothesis of no co-integration between the two variables is rejected at the 5% significance level. Therefore, there is a long-term equilibrium relationship between oil prices and the dollar effective exchange rate given by:

$$LCH_t = 2.66 + 0.43 LOIL_t + z_t$$

z_t being the residuals.

According to this long-term relationship, an increase in oil price by 10% results, everything else being equal, in a dollar appreciation by around 4.3%.

9 In order to select the appropriate model for implementing ADF and PP tests, we follow the traditional sequential procedure: we first estimate the general model incorporating a deterministic trend and an intercept. If the trend is found to be non significant, we then estimate the model with intercept, but no deterministic trend. Finally, if the intercept is not significant, we estimate the model without deterministic trend, nor constant.

10 It should be noted that our aim in this paper is to study the link between the dollar exchange rate and oil prices. Consequently, we do not investigate other possible relationships incorporating other economic fundamentals, such as those mentioned in the Krugman's model.

11 To carry out the Johansen-trace test, we have to specify the number of lags in the underlying VAR in first differences. To this end, we retain the number of lags minimizing information criteria.

The existence of co-integration between the two variables allows to estimate a vector error correction model (VECM) in order to describe the dynamic adjustment of the variables to the equilibrium given by the long-term relationship. The VECM estimation is reported in table 2.

Table 2: Error correction model estimation

	ΔLCH	ΔLOIL
z_{t-1}	-0.008874	0.054404
	[-2.25075]	[2.15787]
ΔLCH $_{t-1}$	0.265092	-0.292383
	[5.07313]	[-0.87501]
ΔLCH $_{t-2}$	-0.020041	0.699690
	[-0.38501]	[2.10206]
ΔLOIL $_{t-1}$	-0.007210	0.203523
	[-0.88532]	[3.90787]
ΔLOIL $_{t-2}$	-0.007081	0.002152
	[-0.87187]	[0.04144]
Constant	-0.000152	0.001464
	[-0.21515]	[0.32494]
Tests on residuals		
LB(4) = 0.1898 ; LB(8) = 0.7875 ; LB(12) = 0.1847		
JB = 0		

z_{t-1}: residuals of the long-term relationship between LCH and LOIL in t-1. Between square brackets: t-statistics of estimated coefficients. LB(k) is the p-value of the Ljung-Box test of no autocorrelation for k lags. JB is the p-value of the normality test proposed by Jarque-Bera.

The results show that the error correction term is negative and significant in the equation of the exchange rate variations[12]. Therefore, there is a mean-reverting process of the exchange rate to its long-term target. However, the adjustment speed is very low (-0.0088), meaning that only about 10% of the adjustment to the equilibrium is made each year. It corresponds to a half-life of deviations of about six years and a half, which is quite long[13]. On the short run, exchange rate changes only depend on their one-period lagged changes; oil price changes depend on lagged (two periods) exchange rate changes and on one-period lagged oil price changes. The diagnostic tests on residuals report no serial correlation. However, the residuals do not have a normal distribution, which is common with financial variables.

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[12] We have $z_{t-1} = LCH_{t-1} - 2.66 - 0.43 LOIL_{t-1}$ in the exchange rate equation and $z_{t-1} = LOIL_{t-1} + 6.13 - 2.30 LCH_{t-1}$ in the oil price equation.

[13] The studies on purchasing power parity usually have results of a half-life between three and five years (Rogoff, 1996).

3.3 Causality study

The existence of a co-integration relationship between the two variables means that at least one of the two variables Granger-causes the other. It is consequently relevant to study the direction of the causality and the nature (exogenous or not) of the considered variables.

We proceed in two steps. First, we test the existence of a long-term causality between the two variables with exogeneity tests. By doing so, we try to determine whether the exchange rate and/or oil price are weakly exogenous according to Engle, Hendry and Richard (1983). It implies to test whether the long-term relationship, captured by the residual, is significant or not in the equations of exchange rate variations and oil price variations. The results of the likelihood ratio test reported in table 3 show that the oil price is weakly exogenous while the exchange rate is not. In other words, the deviation from the long-term target significantly influences the exchange rate but does not affect oil prices.

Table 3: Results of the exogeneity tests (p-values)

Variable	p-value
Exchange rate	0.0245
Oil price	0.7756

In a second step, we study the Granger causality. To this end, we estimate a VAR model in level and we apply the Granger causality tests. Indeed, the fact that the variables are co-integrated allows us to estimate a VAR in level, as shown by Engle and Granger (1987). The results are reported in table 4 for different lags, *p*, in the VAR process.

Table 4: Results of causality tests (p-values)

	VAR(1)	VAR(2)	VAR(3)	VAR(4)	VAR(6)	VAR(8)	VAR(10)	VAR(12)
O ⇏ C	0.0529 *	0.1300	0.1800	0.1124	0.2035	0.2525	0.4485	0.4069
C ⇏ O	0.8473	0.9600	0.1704	0.2591	0.4653	0.5722	0.7687	0.1193

O ⇏ C is for the null hypothesis of no causality from oil prices to the exchange rate.

C ⇏ O is for the null hypothesis of no causality from the exchange rate to oil prices.

* : rejection of the null hypothesis at the 10% significance level.

The null hypothesis is no causality. The main result from table 4 is that the exchange rate does not cause oil prices. It means that even if oil prices are expressed in dollars, the changes in the dollar exchange rate have no significant effect on oil prices. This result confirms the conclusion from the exogeneity tests. For the causality from oil prices to the exchange rate, the conclusion depends on the choice of the model; the causality can be observed, at the 10% level, only for one autoregressive lag.

This result is in line with other studies. In particular, Amano and van Norden (1993, 1995) show that oil prices are weakly exogenous, unlike the exchange rate. These authors evidence a long-term causality from oil prices to the exchange rate. On the long run, the real exchange rate does not cause oil prices (see also Bénassy-Quéré *et al.*, 2007). These results suggest that, even if oil prices are generally denominated in dollars, dollar changes have no significant impact on oil prices.

3.4 Study for the 1980-2004 sub-period

In order to check that our results are not affected by the second oil shock in our sample, we perform the same analysis for the January 1980 to November 2004 sub-period. We will not provide all the details of the estimations here but just sum up the main results[14].

Overall, the results for this sub-period are very similar to those for the whole sample. The trace test indicates that oil prices and the U.S. real effective exchange rate are co-integrated, at the 10% level. Everything else equals, a 10% increase in the real oil prices leads to a dollar appreciation by 4.2%, which is very close to the result obtained on the whole period. The estimation of an error correction model with two lags also gives a significant driving force of the exchange rate to the long-term target. The adjustment speed remains low even if it is slightly higher than for the whole period: it is equal to -0.0109, which means that 12.3% of the adjustment to the equilibrium is made every year, corresponding to a half-life of 5 years and three months. Finally, the results of the causality tests, obtained from a VAR(1) model in level, exhibit a causality from oil prices to the exchange rate at the 5% significance level. Like in the previous section, the null hypothesis of no causality from the exchange rate to oil prices was never rejected, for any lags in the VAR model estimation. Overall, the results for the 1980-2004 sub-period remain consistent with those on the whole period.

3.5 Interpretation and channels of transmission

Among all possible explanations proposed in section 2, only one matches the found positive link from oil price to the dollar. It is the interpretation of an effect of oil price on the dollar exchange rate in the framework of a BEER model *à la* Clark and McDonald (1998). All others give either wrong signs - as portfolio models by Krugman, or wrong directions, as the effects on dollar changes on oil supply and demand.

As the relation is to be interpreted in the framework of a BEER model, we now try to find out the channels of transmission. Following a BEER model, we test whether the U.S. net foreign assets or the U.S. terms of trade are the transmission variables in the relationship between the exchange rate and oil price. To this end, we first test for the existence of a link between the exchange rate and each of both other variables and then we study the impact of oil price on these same variables[15].

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[14] Complete results are available upon request to the authors. Here, we check the robustness of our results by excluding the second oil shock from the sample period. It should be noted that a possible extension of this work is to explicitly deal with structural breaks (such as the 1986 oil price collapse) by incorporating them into the VECM (see Johansen *et al*. (2000) and the extension by Hungnes (2005), and Saikkonen and Lütkepohl (2000)).

[15] The initial data are quarterly based. They are converted into monthly frequency in order to increase the number of observations. Indeed, unit root and co-integration tests are asymptotic and results are reliable only if the number of observations is sufficient. Data were converted in monthly frequency in two different ways. A first method consists in assuming the same value for the three months of a quarter. In the second method, we resort to a linear interpolation. The results are identical with the two methods. We only report the results based on the first method of conversion. Figures A3 and A4 in the appendix depict the evolution of the net foreign assets and of the terms of trade.

Net foreign assets (LNFA) and terms of trade (LTOT) in logarithm being non stationary[16], we test the existence of a co-integration relationship between the real effective exchange rate and each of the two other series. The results are reported in table 5.

Table 5: Co-integration test. Trace statistic

	LCH and LNFA		LCH and LTOT	
Null hypothesis	Trace stat.	p-value	Trace stat.	p-value
No relation	18.54*	0.01	9.36	0.33
At most one relation	2.40	0.12	3.41	0.06

*: rejection of the null hypothesis at the 5% significance level.

These results show the existence of a co-integration relationship between the exchange rate and the U.S. net foreign assets, whereas the terms of trade and the exchange rate are not co-integrated. So, on the long run, the net international position has an impact on the real effective exchange rate. The relationship between the two variables is positive, as expected, which means that more foreign assets result in an appreciation of the dollar exchange rate. Therefore, the long-term relationship between oil prices and the effective exchange rate should be transmitted through the net foreign position and not through the terms of trade. In order to check this hypothesis more thoroughly, we test whether net foreign assets and oil prices are co-integrated. The results given by the trace test are reported in table 6. For more information, we also report the results from the co-integration test between oil prices and the terms of trade.

Table 6: Co-integration test. Trace statistic

	LOIL and LNFA		LOIL and LTOT	
Null hypothesis	Trace stat.	p-value	Trace stat.	p-value
No relation	22.94*	0	7.86	0.48
At most one relation	3.74	0.05	3.11	0.08

*: rejection of the null hypothesis at the 5% significance level.

These results show that oil prices and the U.S. net foreign position are co-integrated. Moreover, there is again no co-integration relationship between oil prices and the terms of trade. So, according to these conclusions, the relationship between oil prices and the dollar real effective exchange rate is transmitted through the U.S. net international position. In the estimation, a 10% oil price increase generates, everything else being equal, an improvement of the U.S. net international position by about 2%. Furthermore, the error correction model estimation (see table A4 in the appendix) shows that the error correction term is negative and significant in the equation of the changes of the U.S. net international investment position.

[16] See table A3 in the appendix. The Dickey-Fuller and Phillips-Perron tests leading to opposite conclusions, we apply a third test: the KPSS test based on the null hypothesis of no unit root. The results (not reported here, but available upon request to the authors) indicate that such a hypothesis is rejected for both series: the net foreign assets and the terms of trade are integrated of order one.

Finally, the adjustment speed is fairly high (the coefficient is equal to -0.2) and the variables do not seem to influence each other on the short run[17].

4. Conclusion

In this paper, we have tried to determine whether there was a link between the real price of oil and the U.S. real effective exchange rate. Overall, our study has exhibited the quite complex interactions between the two variables, especially at a theoretical level. Our empirical results show that there exists a long-term relation (i.e. a co-integration relation) between the two series over the period 1974-2004. As shown in some previous studies, an increase in oil price is linked to a dollar appreciation in the long run. The application of causality tests suggests that the direction of the causality is from oil prices to the dollar exchange rate. However, the adjustment speed of the dollar real effective exchange rate to the long-term target is very slow: the estimation of a vector error correction model has reported half life of deviations to be about six years and a half. We then interpret our results through an exhaustive set of alternative theoretical explanations. Among all proposed explanations, only one is able to match the found sign and direction of the relation. Further investigation shows that an increase in oil price is likely to improve the U.S. net foreign asset position relatively to the rest of the world, and this has a positive impact on the dollar appreciation.

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[17] As previously mentioned, it should be noted that, due to the importance of the NFA variable, it would be interesting to estimate a VECM incorporating this series as a determinant of the real effective exchange rate. Indeed, it seems evident that the real effective exchange rate does not only depend on oil prices, but also on other economic fundamentals, like NFA. While appealing, the investigation of such a relationship is not the aim of the present paper.

APPENDIX

Figures A1 and A2 report the volatility of the dollar's real effective exchange rate and the volatility of oil prices. The volatility series are computed by the square of log-variations of the two variables. The horizontal line represents 1.96 times the standard error of the volatility series.

Figure A1:
Dollar real effective exchange rate volatility

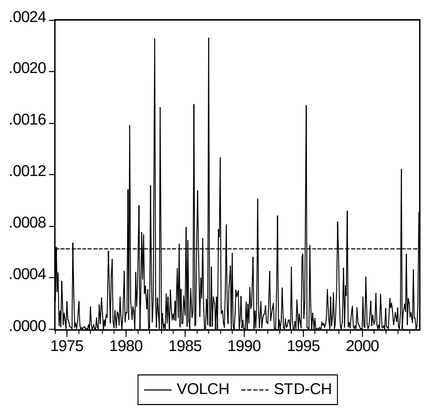


Figure A2:
Real oil price volatility

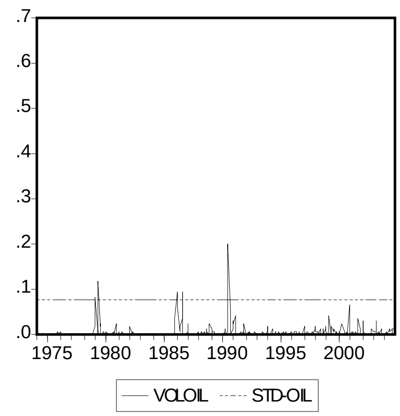


Figure A3:
U.S. net foreign assets (in logarithms, rescaled)

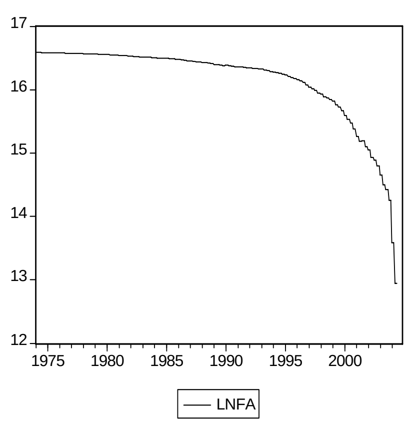
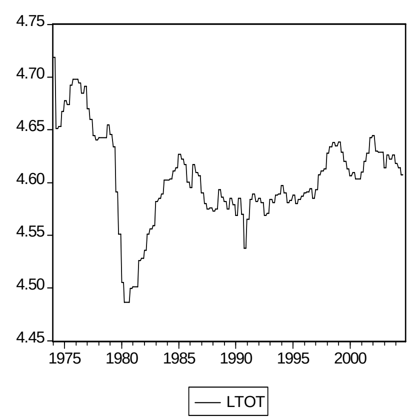


Figure A4:
U.S. terms of trade (in logarithms)



The U.S. net foreign assets variables (figure A3) was given by the Bureau of Economic Analysis. It is computed as the cumulative sum of the difference between row 40 (U.S.-owned assets abroad, net (increase/financial outflow (-)) and row 55 (Foreign-owned assets in the

United States, net (increase/financial inflow (+)) of the U.S. balance of payments. Data are in million dollars and are seasonally adjusted. Moreover, they were rescaled to accept the logarithmic transformation.

Table A1: Unit root tests

	U.S. dollar effective exchange rate (LCH)		Oil price (LOIL)	
	LCH	ΔLCH	LOIL	ΔLOIL
ADF test	-0.30 (1)	-14.55* (1)	0.07 (1)	-15.89* (1)
PP test	-0.29 (1)	-14.36* (1)	0.12 (1)	-15.68* (1)

*: rejection of the null hypothesis of a unit root at the 5% significance level.
(1) model without constant nor trend.

Table A2: Descriptive statistics on first-differenced variables

	ΔLCH	ΔLOIL
Number of obs.	371	371
Mean	-0.0002	0.0019
Standard error	0.0141	0.0887
Skewness	-0.1828	2.5493
Kurtosis	3.5739	25.0536
Jarque-Bera	7.1585 (0.02)	7920.196 (0)

Between brackets: p-value for the Jarque and Bera's normality test statistic.

Table A3: Unit root tests for NFA and TOT in logarithms

	Net foreign assets (LNFA)		**Terms of trade (LTOT)**	
	LNFA	ΔLNFA	LTOT	ΔLTOT
ADF test	1.59 (1)	6.15 (1)	-0.14 (1)	-9.48* (1)
PP test	9.97 (3)	-21.15* (1)	-2.92* (2)	-19.42* (1)

(1) model without constant nor trend. *: rejection of the null hypothesis at the 5% significance level.

Table A4: VECM estimation between the net foreign assets and oil prices

	ΔLNFA	ΔLOIL
ε_{t-1}	-0.006418	-0.002055
	[-4.06998]	[-0.48926]
$\Delta LOIL_{t-1}$	-0.010288	0.326812
	[-0.51668]	[6.16202]
$\Delta LLOIL_{t-2}$	0.010442	-0.176634
	[0.50510]	[-3.20752]
$\Delta LLOIL_{t-3}$	-0.015932	0.104094
	[-0.79853]	[1.95874]
$\Delta LNFA_{t-1}$	-0.106648	-0.123388
	[-2.83732]	[-1.23239]
$\Delta LNFA_{t-2}$	-0.108272	0.003294
	[-2.87270]	[0.03281]
$\Delta LNFA_{t-3}$	0.976906	-0.044169
	[21.7057]	[-0.36843]
Constant	-0.004129	-0.002143
	[-2.40437]	[-0.46856]

Between square brackets: *t*-statistics of estimates. ε_{t-1}: residuals of the long-term relation between LNFA and LOIL in t-1.

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