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THE OIL SINGLE PRICE AND THE DOLLAR

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Abstract

When the exchange rate of the dollar fluctuates, a disequilibrium is created in the market for crude oil. This will be reflected in altered demand for crude oil and/or in an altered oil price. The purpose of this paper is to examine whether a stable long-term relationship exists between real prices of oil and the US bilateral exchange rate against the euro over the 2000-2006 period. We will test the co-integration and the causality study between two variables. Our results suggest that 1% depreciation in the dollar coincides with a 1.95% rise in oil prices in long run (a 1% appreciation in the euro would coincide with a 1.88% rise in oil prices in the long run). The causality runs from the exchange rate to oil Prices. The partial equilibrium model in this paper illustrates that a depreciation of the dollar leads to a higher oil price denominated in dollars.

Keywords*: Oil prices, bilateral exchange rate, co-integration, error correction model, 2SLS, causality, two currency models.*

1- Introduction

Early in the 20th century, the U.S. economy began to dominate the world economy. The U.S. dollar was tied to gold. The Great Depression had substantially increased the amount of currency in circulation, and thus rendered the backing of U.S. dollars by gold impossible. This led Roosevelt to decouple the dollar from gold in 1932.

Economically, the American dominance was born with Bretton Woods in 1945. This established the dollar as the reserve currency of the world. When in 1970-1971 foreigners demanded payment for their dollars in gold, The U.S. Government defaulted on its payment on August 15, 1971. While the popular spin told the story of "severing the link between the dollar and gold", in reality the denial to pay back in gold was an act of bankruptcy by the U.S. Government. From that point on, to sustain the American dominance, the United States search for economic reason to force the world to continue to accept ever-depreciating dollars in exchange for economic goods, that reason was oil.

In 1971, as it became clearer and clearer that the U.S Government would not be able to buy back its dollars in gold, it made in 1972-73 an iron-clad arrangement with Saudi Arabia in exchange for accepting only U.S. dollars for its oil. Because the world had to buy oil from the Arab oil countries, it had the reason to hold dollars as payment for oil. The economic essence of this arrangement was that the dollar was now backed by oil. It was the only acceptable payment for oil. This is one of the important reasons let the dollar, become as a major currency, has played a dominant role in international currency markets.

Because oil is denominated in dollars (oil single price policy), oil price fluctuations in domestic currency may be quite different depending on the exchange rate regime. For instance the rise in oil price was partly cushioned in the Euro-zone by a sharp appreciation of the euro: from January 2000 to December 2006, the oil price rose by 129.8% in dollars, but the dollar depreciated by 38.8% against the euro. Therefore, the fact that oil imports are denominated in US dollars raises the question of the co-movements between oil prices and the dollar exchange rate.

However, this paper addresses the impact of changes in exchange rates euro/dollar on the oil market. The empirical analysis show that the link between the oil price and dollar generally finds a positive relationship between the both variables, i.e. depreciation in the dollar coincides with a rise in the oil price. The causality runs from exchange rate variations to oil price.

The theoretical interpretation, in this paper, of the link between the oil price and the exchange rate, illustrates in the partial equilibrium model that depreciation in dollar lead to an increase in the oil price.

This paper is organized as follows. The relationship between the price of oil and that the exchange rate of the dollar over January 2000 to December 2006 is studied in section 2, through both cointegration analysis and Granger causality tests. Section 3, presents a theoretical model, two currency model where the euro/dollar exchange rate reacts to the oil price. Section 4 concludes.

2-Oil prices and the dollar exchange rate: an empirical analysis

We use daily data of oil prices and dollar exchange rates from 1 Jan 2000 to 31 Dec 2006 from the Federal Reserve, BCE and The international Energy Agency. The oil variable is expressed in real terms, i.e. it is deflated by the US consumer price index. The exchange rate is the dollar real bilateral exchange rate[1] against the euro.

2.1- A first look at the data

Table 1 compare the evolution of the fork of the OPEC basket prices (22-28$) corrected by the dollar real exchange rate (LDER). Firstly we can observe that in 2001 when the dollar appreciated, the fork of OPEC basket prices decreased. Since 2002 the depreciations of the dollar lead the oil price to increase in the long run. Secondly, we notice that a depreciation of the dollar results in a decrease in oil prices outside the USA.

Figure 1 compares the evolution of the dollar real exchange rate (LDER), with the real oil price (LOIL) over Jan 2000 to Dec 2006, in logarithm. Three observations can be made. First, the oil price is more volatile than both exchange rates. Second, the dollar and the oil price seem to move quite in parallel. Third, the exchange rate seems to lead the oil price variable.

We will try to check these visual impressions through an econometrics analysis. The first step is to study the order of integration of both variables. The results of the ADF and PP tests are reported in U1 below. It turns out that both series are integrated of order one.

U1- Unit root tests

Table 1: unit root test

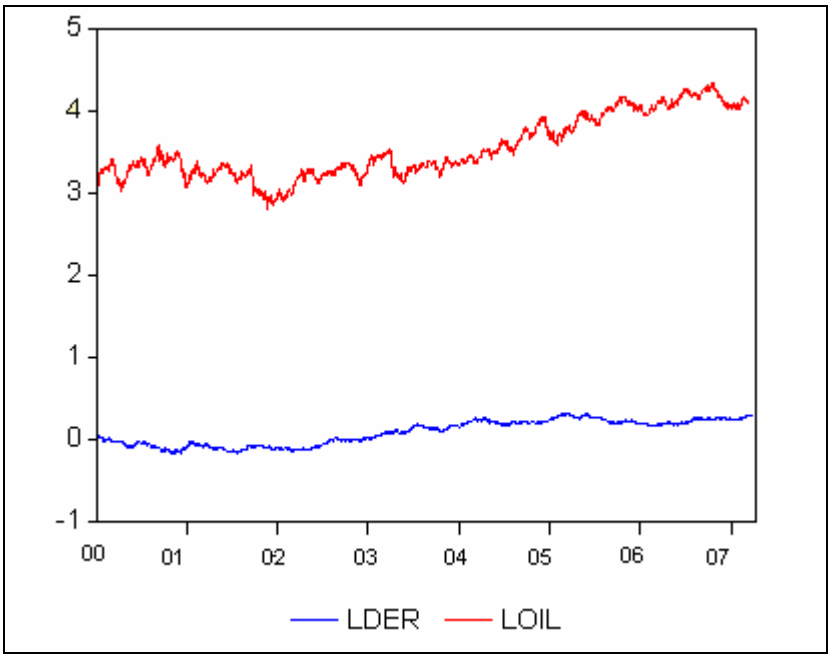
	US bilateral Exchange rate		Oil prices	
	Level	Δ	Level	Δ
ADF test	-0.48	-18.2*	-1.05	-43.6*
PP test	-0.44	-17.9*	-1.03	-43.1*

*: rejection of the null hypothesis of a unit root at the 5% significant level

- This model without constant and without trend

[1]The bilateral Exchange rate is Euro/dollar and Dollar/Euro.

Figure 1: Real exchange rate and real oil price, in logarithm



Source: IEA, FR and ECB

Table 1: real value of the fork of OPEC corrected by exchange rate

	2000	2001	2002	2003	2004	2005	2006
Moyen Exchange rate $/£	0,923	0,896	0,945	1,132	1,243	1,244	1,256
Real value of the fork of OPEC basket prices (22-28)	20,3-5,9[2]	19,7-25,1	20,8-26,5	24,9-31,7	27,4-34,8	27,4-34,9	27,7-35,2

Source: OPEC, FR and ECB

2.2- Co-integration

In order to evaluate a stable long-term relation between the bilateral exchange rate of the dollar and the oil price. We study the cointegration between the two variables.

To this aim, we carry out the trace test proposed by Johansen (1988) and Johansen and Juselius (1990). But before we can complete this test, we need to look up the correlation between them.

In the period 2000-2006, the correlation between the oil price in dollar and the exchange rate (LDER) is 0.79 (positive). Thus, the oil price tended to increase in means when the dollar depreciates (or appreciates in euro) this is called the movement of scissors.

According to the trace test, the null hypothesis of no cointegration between the two variables is rejected at the 5% significance level (table 2). Therefore, there is a long term equilibrium relationship between the oil prices and the dollar exchange rate. The estimation of this relationship shows that depreciation in the dollar by 1% results, all other things being equal, in an oil prices increase by around 1.95% (an appreciation in euro by 1% results, all other things being equal, in an oil prices increase by around 1.88%).

[2] The fork of OPEC (basket prices) 22-28$ corrected by exchange rate.

Here we have a calculated R^2=0.64.This means that 64% of the variance in the oil price is explained by the variance in exchange rate (LDER).

The cointegration between the two variables allows us to estimate a vector error correction model (VECM) in order to describe the dynamic adjustment of the variable to the equilibrium given by the long term relationship. The VECM estimation is reported in table B.

The results show that the error correction term has a negative and significant impact on oil prices log variations. Therefore, there is a mean reverting process of the oil price to its long term target. However, the adjustment speed is very low (-0.00125), meaning that only 1% of the adjustment to equilibrium is achieved each year. Note that the error correction term is negative in the exchange rate equation, meaning that there is no reverting process for the exchange rate towards its long term equilibrium value.

Table 2: Cointegration test

A Loil and Lder series

Null hypothesis	**Trace statistic**	**P-value**
No relation	18.71*	0.03
	LOIL= 3.43 + 1.95 LDER	

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

B*: Error correction model estimation*

	ΔLOIL	**ΔLDER**
Zt-1	-0.00125	0.01515
	[-0.819]	[2.5839]
ΔLOIL(-1)	-0.0247	0.0065
	[-1.050]	[1.0324]
ΔLOIL(-2)	0.02166	-0.0025
	[0.9196]	[-0.493]
ΔLDER(-1)	-0.0807	-0.0170
	[-0.9126]	[-0.721]
ΔLDER(-2)	-0.1942	-0.0398
	[-2.2019]	[-1.6916]
C	0.00058	0.00142
	[0.938]	[1.0338]

2.3- Causality

The existence of a cointegration relationship between the two variables means that at least one of them Granger causes the other. Consequently, it is relevant to study the direction of causality and the nature (exogenous or not) of the considered variables.

We proceed in two steps. First, we test the existence of long term causality between the variables with endogenously tests. By doing so, we try to determine whether the exchange rate and/or oil prices are exogenous. This implies that we should test whether the long term relationship, captured by the residual, is significant or not in the equation of exchange rate log variations and oil prices log variations.

The results of the two stage least squares (2SLS) test reported in table 3 show that the exchange rate is hardly endogenous, this means that the disturbance term of the exchange rate is correlated with the cause of the oil price while the oil prices are not, in term this means that the disturbance term of the oil price is not correlated with the cause of the Exchange rate (exogenous). In other words, the deviation from the long term target significantly influences the oil prices but does not affect the exchange rate.

Table 3: Results of the 2SLS (*P-value*)

Variable	**P-value**
Exchange rate	*0.0245*
Oil prices	*0.3911*[*]

*: acceptation that the dependent variable (LDER) is correlated with the cause of the independent variable (LOIL)

In the second step, we study the Granger causality. To this end, we estimate a VAR model in level and we apply the Granger causality tests. The results reported in table 4 for different lags, P, in the VAR process.

Table 4: Results of causality tests (P-value)

	VAR (1)	VAR (2)	VAR (3)	VAR (4)	VAR (6)	VAR (8)	VAR (10)	VAR (50)
$\boldsymbol{OIL \rightarrow EX}$	0.502	0.455	0.630	0.781	0.859	0.838	0.709	0.678
$\boldsymbol{EX \rightarrow OIL}$	0.033[*]	0.071	0.017[*]	0.032[*]	0.099	0.215	0.287	0.049[*]

$EX \rightarrow OIL$, is for the null hypothesis of no causality from exchange rate to oil prices.
$OIL \rightarrow EX$, is for the null hypothesis of no causality from oil prices to exchange rate.
*: *rejection of the null hypothesis at the 10% significance level*.

The null hypothesis is no causality. Table 3 clearly shows that, we cannot reject the hypothesis that oil prices do not Granger cause exchange rate, but we do reject the hypothesis that exchange rate does not Granger cause oil prices. This means that exchange rates cause oil prices. It means that even if oil prices are expressed in dollars, the changes of the dollar have a significant effect on oil prices. It appears that Granger causality runs one way from exchange rate to oil prices and not the other way. For the causality from exchange rate to oil prices, causality can be observed, at the 10% level, for four autoregressive lags.

3- The exchange rates and the market for crude oil

3.1- Crude oil prices in purchasing countries with different national currencies

The model proposed here aims a studying whether the nature of the link between the exchange rates and the oil price. Most primary commodities are priced in American dollars. However, trade goes to a large extent between countries that do not have the dollar as their national currency. Thus, the US dollar is a common converting unit for all actors in the market. However, the price faced by each buyer and seller in the market is the price of the commodity determined in dollar multiplied by the country's exchange rate against the US dollar.

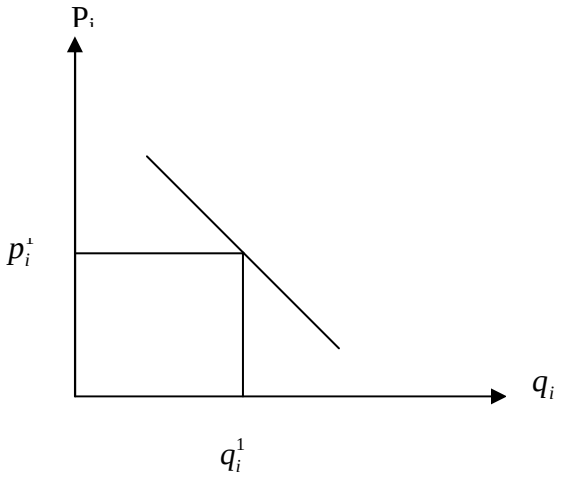
Our model consist two countries. Country US and country EU; the united stats of America is country US and European Union is country EU. The demand for crude oil in each country (q_i, i= US and EU) can de expressed as a function of the price (P_i) denominated in their respective national currencies.

$$q_{US} = f(p_{US}) \text{ , where } f' < 0$$

$$q_{EU} = g(p_{EU}) \text{ , where } g' < 0$$

The demand for crud oil is assumed to fall with increasing price. For any given price the demand in each country is determined:

The demand for crude oil in country i



For US, the demand curve will be aggregate of EU national demand curves for crude oil.[3]

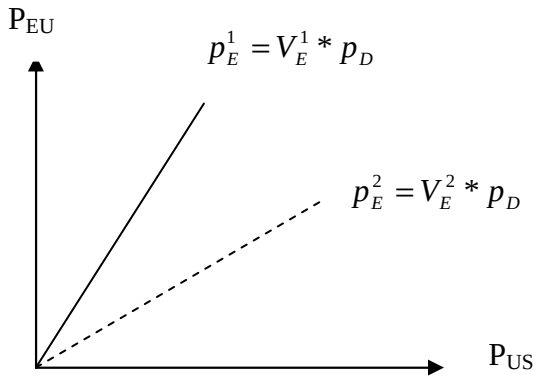
The difference between the two countries national prices is represented by the exchange rate between their currencies.

$$p_E = V_E * p_D$$

V_E is the number of units of euro currency per unit of dollar currency. The price of crude in EU fluctuates according to changes in the currency rate, at a given price of oil in dollar currency. Thus, the relationship between the two oil prices can be expressed as a ray from the origin with the two oil prices on the axes. The initial rate is illustrated in the figure below by the slope of the ray V_E^1. For any price in country US's currency, there is a corresponding price in country EU's currency. The difference results from the exchange rate.

[3] We consider taxation levels on petroleum and other internal factors in the two countries to be constant. Fluctuating exchange rates will also alter the prices of all goods paid in dollars. This will give contribution to substitution between dollar paid goods and goods paid in other currencies. The nation national incomes and assets will change as a result of the altered exchange rates as well. These substitution and incomes effects are unsure in direction and strength and are excluded in this analysis.

The relations between oil prices in the two countries



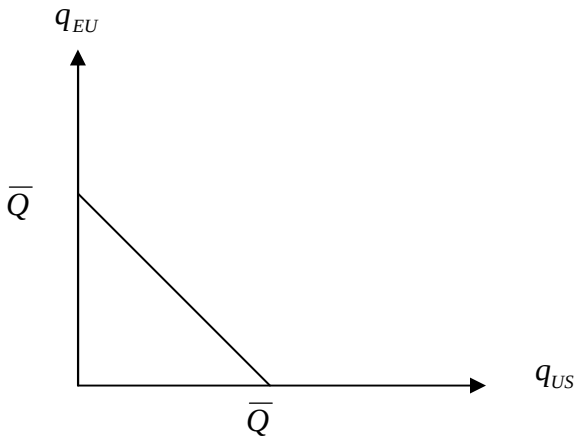
If the dollar is depreciated, EU has to pay less unit of euros currency per unit of dollar currency, and the slop of the ray will change from V_E^1 to V_E^2. Now EU has to pay less per barrel of oil than before, at a given price of oil determined in dollar currency (this means with the depreciation in dollar the oil price in EU decrease). In the figure above this is expressed by a downward turn to ray, and oil price in euro currency change from P_E^1 to P_E^2, where $P_E^1 > P_E^2$. The euro is then de facto evaluated, either through an administered evaluation in euro currency, an administered depreciation of the dollar currency, or a change in the exchange rate between the currencies caused by the other forces in the market.

We assume that the actual purchase of oil by the two countries equal the total supply of oil, Q. Thus the total supply of oil is given in this model.

$$q_{EU} + q_{US} = Q$$

Graphically this equation can be illuminated as in the figure below:

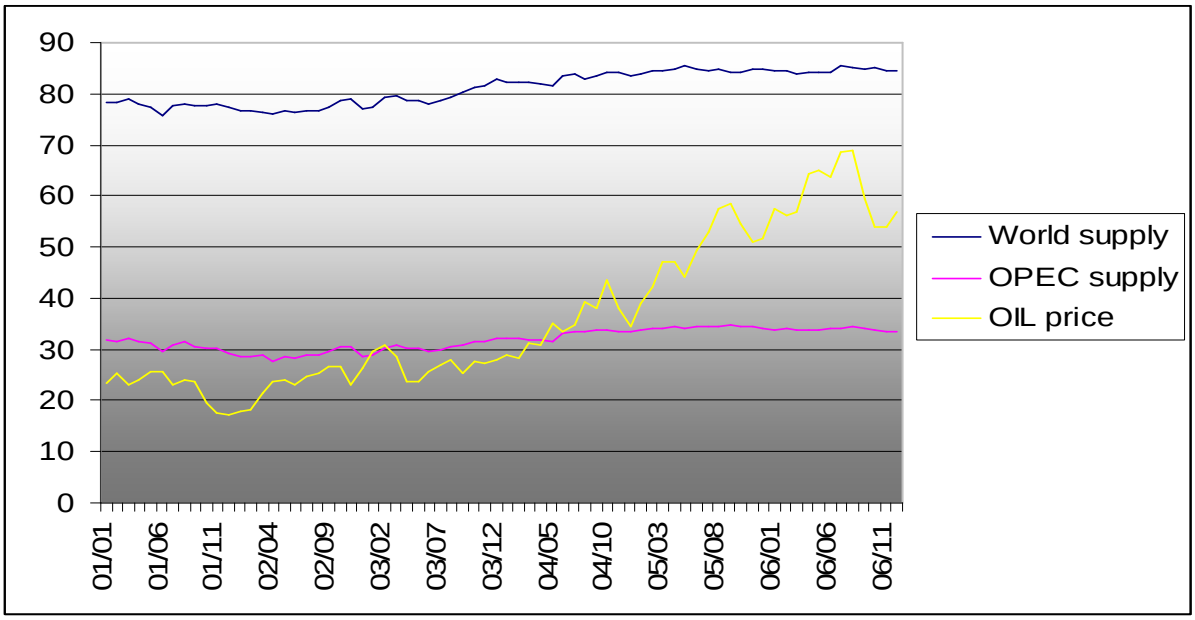
Possible distributions of crude oil supply between the two countries



The supply is assumed to the totally inelastic and will not be influenced by the changes in the price. Thus, in our partial equilibrium model, a certain level of demand in the one country directly determines the demand in the other. This is a simplification done because it is useful for analysing the problem at hand. However, to include supply changes in this pure economic model would have to assume that, in one way or another, the supply side would react unique to price changes. Experts disagree how oil supply react to change in oil prices. Some experts even claims that prices are only a minor factor of in the determination of crude oil supply. It is political factors and economic factors that determine the supply of crude oil. For example the Arab-Israel war in 1973 that the Arab had decreased his production of oil that is cooperation between them against Israel. And the decisions of the OPEC since 2000 (reduction and increase quotas) aimed at maintaining the price of reference (OPEC basket price) for economics objectives. Thus, as a pure price quantity scheme seems to be

too unsure and/or too simple to describe supply side behaviour, we exclude this discussion by considering supply exogenously in our model.

Relationship between oil prices, the world and the OPEC supply.



Source: EIA

3.2- Analytical model for oil prices and exchange rate

$$q_E = f(p_E)$$
$$q_D = g(p_D)$$
$$p_E = V_E * p_D$$
$$q_E + q_D = Q$$

The system consists of 4 equations and 6 variables (q_E, q_D, p_E, p_D, V_E, Q). We assume Q to be exogenously determined in the model (the supply is kept constant), thus changes in the system are dependent upon the determination of the exchange rate.

Differentiating:

$$dq_E = f' * dp_E$$
$$dq_D = g' * dp_D$$
$$dp_E = V_E * dp_D + dV_E * p_D$$
$$dq_E + dq_D = 0$$

Reorganizing, gives the following results from altering the exchange rate. The model (1) with $p_D > 0$, $V_E < 0$, $p_E < 0$ (depreciating the dollar).

$$\frac{dp_E}{(-dV_E)} = \frac{-g' * p_D}{g' + f' * V_E} < 0$$

The price of oil in EU decreases. A depreciation of the dollar results in a decrease in oil prices outside of the USA (Europe).

$$\frac{dq_E}{(-dV_E)} = -\frac{f' * g' * p_D}{f' + g' * V_E} > 0$$

The decrease in price in EU implies an increase in demand in that country. A depreciation of the dollar in relation to other oil importers currencies causes for an increase in the oil demand in EU (outside USA).

$$\frac{dp_D}{(-dV_E)} = \frac{f' * p_D}{f' + g' * V_E} > 0$$

Equilibrium in our model implies an increase in US's price. A depreciation of the dollar in relation to other oil importers currencies causes the crude oil price in dollar to increase.

$$\frac{dq_D}{(-dV_E)} = -\frac{dq_E}{(-dV_E)} = \frac{f' * g' * p_D}{f' + g' * V_E} < 0$$

The demand for oil in USA decreases. A depreciation of the dollar towards other oil importers currencies causes the demand for oil in USA to decrease.

Reorganizing, gives the following results from altering the exchange rate. The model (2) with $p_D < 0$, $V_E > 0$, $p_E > 0$ (appreciating the dollar).

$$\frac{dp_E}{(dV_E)} = \frac{g' * p_D}{g' + f' * V_E} > 0$$

The price of oil in EU increases. An appreciation of the dollar results in an increase in oil prices outside of the USA (Europe).

$$\frac{dq_E}{(dV_E)} = \frac{f' * g' * p_D}{f' + g' * V_E} < 0$$

The increase in price in EU implies a decrease in demand in that country. An appreciation of the dollar in relation to other oil importers currencies causes for a decrease in the oil demand in EU (outside USA).

$$\frac{dp_D}{(dV_E)} = \frac{-f' * p_D}{f' + g' * V_E} < 0$$

Equilibrium in our model implies a decrease in US's price. An appreciation of the dollar in relation to other oil importers currencies causes the crude oil price in dollar to decrease.

$$\frac{dq_D}{(dV_E)} = -\frac{dq_E}{(dV_E)} = -\frac{f' * g' * p_D}{f' + g' * V_E} > 0$$

The demand for oil in U.S.A increases. An appreciation of the dollar towards other oil importers currencies causes the demand for oil in USA to increase.

The model (1) can be illustrated as in the figure below. In the first quadrant we illustrate the distribution of total supply of crude oil, in the second quadrant the demand for crude oil in EU, in the fourth quadrant demand for oil in US and in third quadrant the rays V_E^i (i=1, 2) illustrate the relationship between the prices in the two countries with two different exchange rates between them.

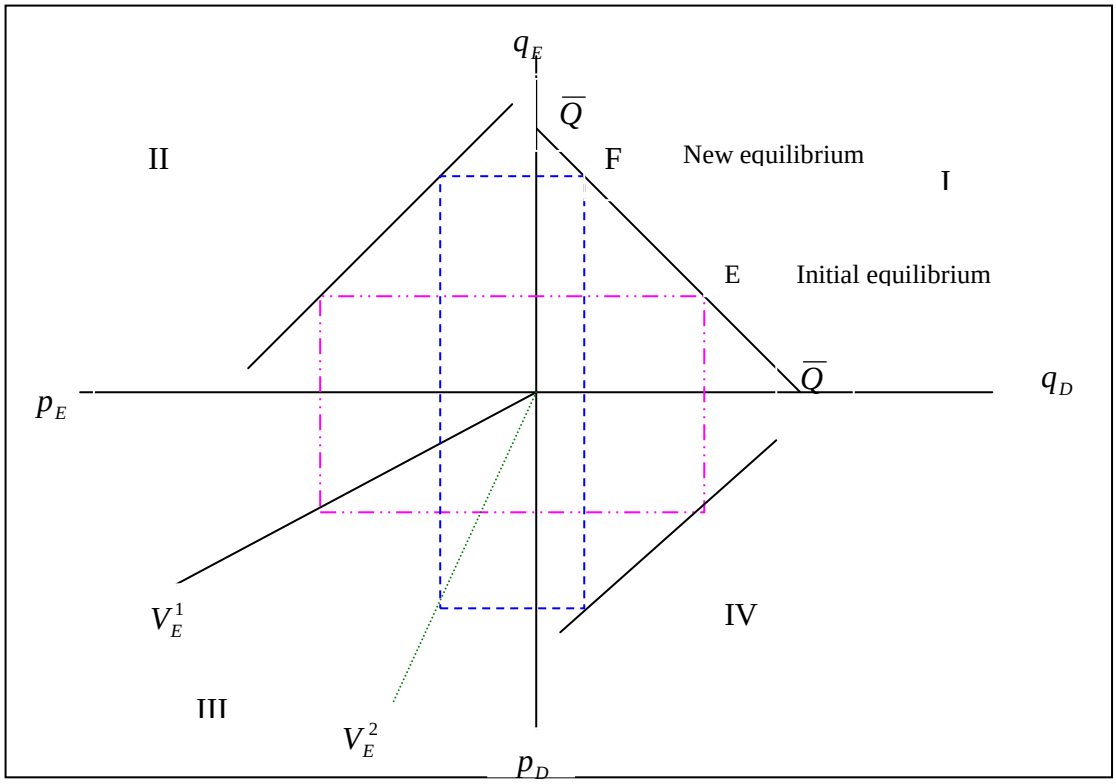
Initially equilibrium is at point E, where demand is distributed between the countries at the prevailing prices and exchange rates. This initial equilibrium is illustrated by the thicker broken lines.

If the dollar currency is devaluated, the relationship between the national oil prices is affected. This is expressed by a turn of the ray from V_E^1 to V_E^2 in the third quadrant.

After the devaluation the initial distribution of crude oil no longer represents equilibrium since it is not consistent with the new relationship between the prices in the two countries.

The new equilibrium is at point F, where the oil price in US has increased. This implies that demand decrease in that country. Accordingly, the price in EU has decreased, as the demand for oil in this country has increased. Thus, a switch in oil consumption from US in favour of EU has taken place.

Graphical model for oil prices and exchange rates



In this model the quantity effects of devaluation will be of the size in both countries, with opposite signs. The decline in consumption in one country will be met by a corresponding rise in consumption in the other country[4].

Thus the numerical value of the elasticity of demand in each of the countries with respect to the exchange rate can be expressed as:

$$\left|El_{V_E} q_i\right| = \left|\frac{dq_i}{dV_E}\right| * \frac{V_E}{p_i} = \left|\frac{f' * g' * p_D}{f' + g' * V_E}\right| * \frac{V_E}{p_i} .(i = E, D)$$

This elasticity gives an expression of how many per cent q_i will change when V_E changes 1 per cent. It illustrated that a low numerical value of the demand derivatives with respect to prices, f' and g', also correspond to low numerical value of the demand elasticity with respect to exchange rates. Since demand elasticity have the same sign as the corresponding demand derivatives but give an expression of relative as apposed to absolute changes, we can conclude from this that the transfer effect in quantity of a devaluation of one of the currencies is less the more inelastic the demand is with respect to national prices. The demand elasticity with respect to prices in one of the countries will have an equally strong impact on the demand elasticities in the country itself.

However, depreciation in the dollar will not necessarily result in a total redistribution of volume of oil between US and other importing countries. Because of a rigid production structure and the other features unique to the USA, there will be some limitations on how much oil the nation can absorb in the short run, independent of price,. In addition to the downward pressure on the dollar price of the price of oil in adjustment towards a new equilibrium, a depreciation of the dollar would probably result in increasing the total quantity demanded as well.

The elasticities of the national prices with respect to the exchange rate between the two countries currencies can be expressed as:

[4] This can be seen directly from graph supply.

$$El_{V_E} p_i = \frac{dp_i}{dV_E} * \frac{V_E}{p_E} \Leftrightarrow \quad >0 \text{ if i=EU, } <0 \text{ if i=US.}$$

The first and the third equations in the models, respectively, provide us with the sign of the above equations for each country. From these, we can see that the differences in the numerical value of the two countries derivatives of process with respect to exchange rates is the numerical value of the demand derivatives with respect to prices, f' and g'. In relative terms, this implies that the difference between the numerical value of the elasticities of national oil prices with respect to the exchange rate is also is the numerical value of f' and g'.

$$\left|El_{V_E} p_E\right| \gtreqless \left|El_{V_E} p_D\right| \quad \text{If} \quad |g'| \gtreqless |f'|$$

This means that the elasticities of prices with respect to the exchange rate depend on the elasticity of demand in each of the countries with respect to national oil prices. That implies that the changes in oil prices in the devaluating country will be larger the more inelastic demand is with respect to prices in that country. The effect will be smaller the more inelastic demand is with respect to prices in the other country.

Thus, a depreciation of the dollar leads to an increase for oil denominated in dollars the more elastic demand is in the EU and the more inelastic demand is in USA.

Experts do not always agree whether production of the oil will rise or fall with fluctuating of oil price. The picture becomes even more complex when also political factors are added. In the model, we have assumed that supply is kept constant; i.e. that supply is exogenously determined. However, if i.e. supply increase with increasing prices, a depreciation of dollar will lead to increased production of oil in that country, and decrease production of oil in the EU[5]. Thus, a depreciation of the dollar would normally lead to a decrease in world oil supplies, as supply to the world oil market is much larger from outside than from inside the US[6]. If supply reacts negatively to prices increase, the equivalent arguments can be done, with the signs reserved. To say more precisely how total supply will react to exchange rate fluctuations one would have include more comprehensive models for the crude oil market, which in their turn would require precise presumptions about the frames for an rules of the market, both in the economic and political sense.

The increase in total demand and probable decrease in total supply resulting from the depreciation of the dollar creates in and of itself an imbalance in the market. This results in further downward pressures on oil prices denominated in dollar.

The US share of the oil market also is one of the factors determining to which degree changes in the value of the dollar have an impact on oil prices. If the US has a small market share the dollar is less representative for denominating the oil prices than if they have a larger share of the market. The dollar price will have to change more to balance an imbalance in the market the smaller the US share of the world oil market and the entire system will be more volatile.

[5] We have a positive relationship between the drilling activities and the oil prices. when the oil prices increase the drilling activities increase with it. But this notion has changed drastically since 1999, caused the introduction of euro or the oil price collapse in 1998.

[6] In our model, if the supply decreases, the line Q-Q in the first quadrant will shift to the left in the figure up.

4- Conclusion

In this paper, we have to tried to determine whether there was a link between the real price of oil and the US real exchange rate. First, our study has exhibited the quite complex features of the relation between the two variables. More specifically, our results have shown that there exists a long term relation between the two series. The application of causality tests made it clear that the direction of the causality is from exchange rate to oil price over Jan 2000 to Dec 2006. Our estimates suggest that, other things equal, 1% depreciation in the dollar leads to 1.95% rise in the oil price in the long run. The estimation of the error correction model show a slow adjustment has reported a very slow adjustment speed of the dollar real exchange rate to the long term target. In second step, we introduced a partial equilibrium model of the oil market to illustrate how oil prices both in US dollar and other currencies, react to fluctuations in exchange rate (two currency model). Our analysis is based on an extension of Austvik model. The equilibrium model illustrates that a depreciation of the dollar leads to a higher oil price denominated in dollar.

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