Crude Oil Prices and the USD/EUR Exchange Rate: A Forecasting Exercise*

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Abstract

If oil exporters stabilize the purchasing power of their export revenues in terms of imports, exchange rate developments (and particularly, developments in the US dollar/euro exchange rate) may contain information about oil price changes. This hypothesis depends on three conditions: (a) OPEC has price setting capacity, (b) a high share of OPEC imports come from the euro area and (c) alternatives to oil invoicing in US dollar are costly. We give evidence that using information on the US dollar/euro exchange rate (and its determinants) improves oil price forecasts significantly. We discuss possible implications that these results might suggest with regard to the stabilization of oil prices or the adjustment of global imbalances.

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1. Introduction

Due to the recent oil price shock, economists have devoted an increasing share of their effort to the analysis of energy markets. Similarly, the continuous build up of global imbalances keeps on triggering their dedication with exchange rate issues. Despite these co-occurring events, little attention has been paid to the relation between oil prices and exchange rates. Only few economists have shown an active interest in the following question: Is it just coincidence that crude oil prices soar while the US dollar depreciates simultaneously to record levels?

To the extent that oil exporting countries aim to stabilize the purchasing power of their (US dollar) export revenues in terms of their (predominantly euro-denominated) imports, changes in the US dollar/euro exchange rate may mirror themselves in their pricing behaviour. The plausibility of this theory hinges at least on three conditions: First, oil exporters have some price setting capacity. Second, oil exporters receive a substantial share of their imports from Europe, and particularly from euro area countries. Third, for good reasons, oil invoicing takes place in US dollar.

In this study we analyze the forecasting ability of the US dollar/euro exchange rate for oil prices. In particular, we analyze whether including information on the exchange rate and its determinants in simple time series models of the oil price improves their predictive power.

Apart from the obvious motivation of enlarging our understanding of oil markets and improving oil price forecasts, there are also a number of pertinent economic debates related to this research path. One issue at stake, for instance, is the contribution of oil exporting countries to persistent global imbalances. The surge in oil prices since the end of the nineties has lead to rising current account surpluses of oil exporting countries, outpacing those of Asian emerging economies and corresponding to a major part of US current account deficits. As a consequence, the US Treasury has suggested that "*(…) oil exporters should consider the role that the choice of foreign exchange regime can play in the adjustment process*" (McCown, Plantier et al., 2006, p.7). The IMF concludes from this debate that "*[h]igher spending [of oil producing countries] (…) would help (…) contribute to reducing global imbalances*" (IMF, 2006, p.81). Given that oil exporters import (industrial) goods and services predominantly and increasingly from Europe and Asia rather then the USA (see for example Ruiz Perez and Vilarrubia, 2006) and diversify their investment away from dollar-denominated assets (Bank for International Settlements, 2006), it is not obvious that this recommendation will be fulfilled. Indeed, it is usually argued that petrodollar recycling may have exacerbated global imbalances as it may have alleviated the dampening effect of the current oil shock on European growth (European Commission, 2006). The impact of oil prices on Europe, furthermore, has already been moderated by the appreciation its currencies – in particular of the euro – to the US dollar.

This contribution is also related to the research agenda on the nexus between commodity prices, currencies and their fundamentals. Chen, et al. (2008) successfully forecast commodity prices with the use of exchange rates of important "commodity currencies", i.e. of economies with floating exchange rates and a substantial share of commodities in their exports. The explanation to this phenomenon provided by Chen et al. (2008) relates to the fact that commodity currencies embody important information about future commodity price movements, while commodity markets are less forward-looking. In this sense our paper contributes as an extension of their approach to non-commodity currencies, while presenting a complementary explanation.

Other related debates are that on the future international role of the euro as a reserve or invoicing currency (Kamps, 2006); the monetary policy dilemma of oil exporters caused by the so-called Dutch disease (Corden and Neary, 1982) in the context of the curse of natural resources phenomenon (Sachs and Warner, 1995); or the discussion over the general impact of foreign exchange rate volatility on the real economy (Aghion, Bacchetta et al., 2006). Understanding the relation of exchange rate and oil price developments could potentially alter our perception of the past and recent oil price shocks, e.g. as a monetary phenomenon (Barsky and Kilian, 2001) or as an endogenous response to dollar depreciations.

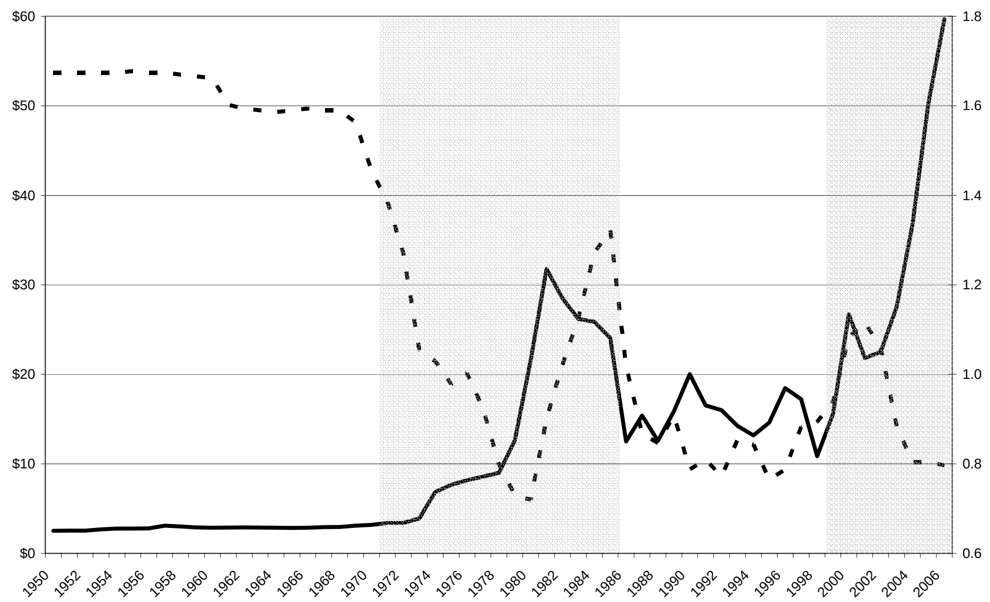
The remainder of the paper is organized as follows. Section 2 exposes some stylized facts and introduces a review of the theoretical and empirical literature on the relation between oil and exchange rates. Section 3 discusses the three conditions commented above of our hypotheses on oil markets, terms of trade and oil invoicing. In Section 4 we present the forecasting exercise. Section 5 concludes.

2. History, theory and previous evidence

2.1. A short contemporary history of oil prices and the dollar exchange rate

During post-war economic history (1950 to 2006) roughly four periods can be distinguished in terms of the relationship between the oil price and the euro exchange rate of the US dollar. Figure 1 shows annual time series of US import crude oil prices (source: International Energy Agency) and nominal US dollar/euro exchange rates (the synthetic euro is used for the period prior to 1999, source: Bank of International Settlements).

Figure 1: Oil prices (bold, left axis) and the US dollar/euro exchange rate (dashed, right axis)



The four periods can already be visually discerned in terms of different volatility and degree of co-movement of these two variables. Interestingly, these periods coincide with important regime shifts in both markets. No temporal delimitation based on historical events can go without some degree of arbitrariness. Nevertheless the distinction is also reflected by changing correlations (see Table 1). While the whole sample delivers a correlation coefficient of –0.61, the four periods vary quite substantially in terms of sign and size of this correlation, a result which is also confirmed by rolling correlation exercises.

Table 1: Periods of correlation between US dollar exchange rate and oil prices

Period	Time spread	Key element	Volatility	Correlation
1	1950 to 1970	Bretton Woods System	low	–0.62
2	1971 to 1984	Oil supply shocks I and II	high	–0.18
3	1985 to 1998	OPEC collapse	medium	+0.44
4	1998 to 2006	Emerging market demand	high	–0.73

The first period between 1950 and 1970 coincides with the existence of the Bretton Woods system of fixed exchange rates, introduced in 1946. The commitment to the convertibility of the US dollar to gold at a fixed rate created a *World Dollar Standard* (McKinnon, 2005), i.e. all exchange rates have been anchored to the (gold) dollar. During this *Golden Age* (Marglin and Schor, 1990) of low inflation, low interest rates and high growth, crude oil prices remained remarkably stable and low. The price formation process took place under the control of the so-called *Seven Sisters*, i.e. those seven oil companies that dominated mid-20th century oil production, refinement, and distribution.

This period of extraordinary stability was followed by an episode of rupture between 1971 and 1984, which is usually associated with the first and second oil shock of 1973 and 1979, respectively. Already before the first oil shock, the so-called *Nixon Shock* (see for example Kuroda, 2004) occurred on August 15, 1971, when US president Richard Nixon announced the discontinuation of gold convertibility of the US dollar given the deteriorating US balance of payments. This resulted in a steep depreciation of the value of the US dollar against gold and many other currencies, notably the German mark and the Japanese yen. Since oil was invoiced in dollars, this implied that oil producers were receiving fewer revenues for the same price. The Organisation of Oil Exporting Countries (OPEC) was initially slow in adjusting prices to reflect this depreciation.

Only two years later, during the Yom Kippur War, OPEC cut production of oil, and placed an embargo on shipments of crude oil to the West. As a result the oil price quadrupled by 1974 to nearly 12 US dollar per barrel. The second oil crisis occurred in the wake of the Iranian Revolution, which temporarily shattered oil production in the country. The subsequent panic and a phased decontrol of oil prices by the Carter administration triggered another boost of crude oil price over the next 12 months to almost 40 US dollar. Prices moderated slightly despite the ongoing First Gulf War, but remained at a high level.

Meanwhile the dollar started to regain strength due to the so-called *Volcker Shock*. By limiting money supply and abandoning interest rate targets, the Chairman of the Federal Reserve, Paul Volcker, successfully trimmed down inflation by more then ten percentage points in two years, entailing, however, a significant recession. The negative correlation between the US dollar exchange rate and the crude oil price can be observed until 1985.

Between 1985 and 1998 the correlation between exchange rate and oil prices diminishes in absolute value, while both remain remarkably stable (see also Krichene, 2006). This period is characterized by the collapse of the OPEC cartel and a weak US dollar following the *Plaza Accord* concluded by G7 countries. In August 1985, Saudi Arabia renounced to act as a swing producer, cutting production in order to stem price decreases. Instead, they linked their oil prices to the spot market for crude and more than doubled their extraction quantity. By mid-1986, crude oil prices dropped below 10 US dollar per barrel. For the rest of the period oil prices remained weak and attempts of OPEC to set price targets failed, not least because rapidly growing spot, forward and futures markets brought about greater price transparency and independence.

In September 1985, the Plaza Accord was signed by five nations with the aim to depreciate the US dollar in relation to the Japanese yen and German mark in order to help the US to reduce its current account deficit and to emerge from a serious recession. Over the next two years, coordinated central bank intervention in currency markets caused a depreciation of the US dollar against the yen by more than 50%. The decline of the US dollar exchange rate was slowed by the *Louvre Accord* of 1987 but its recuperation had to wait until the mid of the next decade.

The price of crude oil boosted temporarily in 1990 during the Iraqi invasion of Kuwait but after the subsequent *Second Gulf War* crude oil prices declined interruptedly, partly squeezed by transition recessions in Former Soviet Union and Central and Eastern Europe (Borensztein and Reinhart, 1994), reaching their deepest level throughout the Asian Crisis of 1997–98.

The last period from 1999 until now is marked by an oil price pickup which has been essentially driven by demand from emerging markets, in particular from China. The failure of oil producers to anticipate the fast rebound of the Asian economies and low levels of exploration investment due to low prices in the 1990s led to insufficient supply. On top of the demand-driven oil price surge we also witness a revival of some OPEC market power, as announced production cuts have now again been at least partly effective. Additionally, potential mismatches between supply and demand as well as the nervousness about geopolitical tensions give rise to speculation which tends to exacerbate the overshooting market.

At the beginning of this period the US dollar got support from the booming US economy. However, from around 2002 onwards the relation between the US dollar exchange rate and oil prices became again clearly negative. Accumulating US external imbalances built up pressure on the US dollar, which recently has been aggravated by a diminishing positive interest rate differential and a mounting negative growth differential in comparison to the euro area.

As this short overview suggests, any meaningful interpretation of the behaviour of the data has to be acquainted with geopolitical and historical economic events. Notwithstanding the difficulties of abstracting from them, some theories of a general nature have already been proposed.

2.2. Theoretical models of the oil price – exchange rate link and empirical evidence

The exchange rate/oil price link has been defined as a kind of *natural relationship* by Mundell, 2002, p. 1): "*[t]here is a definite link between monetary policies, exchange rates and commodity prices (…)*". This view acknowledges the simple truth that changes in prices might also reflect changes in their numéraire. With the gold-dollar-standard it has been obvious to price and quote homogenous goods like commodities using the US dollar. Later, under flexible exchange rates, markets stuck to the dollar, partly because having only one reference and vehicle currency is efficient. Yet, the extreme instability of the foreign value of the US dollar has translated into dollar prices of commodities such as crude oil.

The underlying causes of this apparent link between the commodity price cycle and the dollar cycle, however, is debated. They may mutually affect each other or be both caused by common factors. Depending on the channel highlighted by the corresponding theory, the link might either be positive or negative, or might change from one period to the other.

The explanation we put forward in this study is neither new nor complicated: oil exports simply try to maintain their purchasing power (see also the arguments in Amuzegar, 1978). Following up on the role of the dollar as a numéraire of standard commodities (dollar commodities), a change in dollar exchange rates alters the terms of trade between any pair of countries, the extent of this change depends on the proportion of "dollar goods" relative to "nondollar goods" in their trade structure (see also Schulmeister, 2000). Since the difference between the export and the import share of dollar goods is greatest for oil-exporting countries, their income position is most strongly affected by dollar exchange rate fluctuations. Hence, they have an incentive to react to a dollar depreciation by increasing export prices, as long as they have pricing power.[1]

There are various other hypotheses leading to the same conclusions concerning the link between the two variables (see for example Cheng, 2008). Apart from the described supply side *purchasing power channel,*[2] there is arguably also a demand side *local price channel* at work. According to Austvik (1987), fluctuations in the exchange rate of the US dollar create disequilibria in the market for crude oil. Dollar depreciation makes petrol less expensive for consumers in nondollar regions (in local currency), thereby increasing their commodity demand which eventually causes adjustments in the oil price denominated in US dollars. An additional *asset channel* is put in motion, as a falling US dollar reduces the returns on dollar-denominated financial assets in foreign currencies, hence increasing the attractiveness of oil and other commodities as a class of alternative assets to foreign investors.

[1] Note that their reaction might be asymmetric, as they tend to tolerate dollar appreciation rather than depreciation.

[2] Note that Alhajji (2004) also observes that dollar depreciation reduces activities in drilling activities in Europe and Middle East.

Furthermore their attractiveness rises as well as a hedge against inflation, since dollar depreciation raises risks of inflationary pressures in the United States. Co-movements could also be educed by a *monetary channel,* as dollar depreciation entails monetary easing elsewhere, including oil producing countries with currencies pegged to the dollar. In turn, lower interest rates increase liquidity, thereby stimulating demand, together with that for oil (Cheng, 2008). Finally, a *currency market channel* might be at work as well, since foreign exchange markets are possibly more efficient than oil markets and hence anticipate developments in the real economy that affect the demand and supply of oil (Chen, Rogoff et al., 2008).

The causality of this last channel only appears to go from the dollar to oil prices, while it is actually just secondary to an underlying relation which runs in the opposite direction. In this sense hypotheses on a negative relation from oil to the US dollar might complement rather than substitute the here favoured reverse direction of causality.

Similarly, both relative price developments may have common causes. Most prominently, the hypotheses that real oil and other commodity price developments are influenced by interest rates (Frankel, 2006) in combination with the theory of (uncovered) interest rate parity of exchange rates would allow such an rationalization.

One of the above mentioned channels might dominate the relationship, which does not exclude the influence of even (temporarily) contradictory forces. Krugman (1980), for instance, proposed a three-county model where the direction of the effect depends on a comparison of balance of payment effects of higher oil prices with those of petrodollar recycling. Initially the relation would be positive as oil profits are invested in US dollar assets, but it might turn to negative in the long run since over time OPEC's spending rises with a preference for manufacture products from say, Germany. Extensions of this model by Krugman (1984) deliver similar outcomes, namely that an oil shock affects all countries, and its exchange rate effects arise from asymmetries between countries. The same asymmetries determine the outcome of the above mentioned purchasing power channel.

Ultimately the question which of these factors dominates, can only be approached by empirical evidence. Table 2 collects the most relevant pieces of literature, which display a great variety of estimation results due to differences in theoretical concepts, data definition and temporal delimitation.[3] Over time, the negative relation between the US dollar and oil, driven by the exchange rate, gets increasing support (Krichene, 2005; Yousefi and Wirjanto, 2005; Cheng, 2008). Still, a considerable faction of authors disagrees (Amano and van Norden, 1998; Bénassy-Quéré, Mignon et al., 2005; Schimmel, 2008).

The impact of oil prices on exchange rates of currencies other than US dollar have at least partly been confirmed by various researchers (Akram, 2004; Chen and Chen, 2007; Habib and Kalamova, 2007; Korhonen and Juurikkala, 2007). Typically, such studies focus on currencies of oil exporting countries, where the nexus arises more directly than in the case of the US dollar. The apparent difference in terms of direction of causality between these results and most studies on the dollar oil relation indicate that the US dollar could be an exception due to its role as the oil invoicing currency.

Recently, related studies on a more general link between exchange rates and commodity prices have delivered important results. In the case of freely floating *commodity currencies*, there seems to be more evidence on the direction that commodities are affected by currencies than vice versa (Clements and Fry, 2006; Chen, Rogoff et al., 2008). On a broader, less selective sample of commodity currencies, however, the opposite conclusion can be drawn (Cashin, Cespedes et al., 2004).

[3] One noticeable detail is that most studies use real instead of nominal data. However, we regard nominal data as more appropriate since oil prices contribute directly and indirectly via other input costs, such as energy or other commodities, to inflation. Thus, inflation adjustment removes some important information of this relative price.

Table 2: Selection of studies on the relationship between crude oil price and US dollar exchange rate

Study	Direction	Causality	Theory	Model	Period	Data FX	Data Oil	Method
Cheng, 2008	Short- and long-term negative (except 1980s)	USD → Oil	Purchasing power, local price, asset, and monetary channel	Demand-supply-framework (Borensztein/Reinhart 1994)	1980-2007	NEER and REER USD	Average petroleum spot price	Dynamic Ordinary Least Squares
Bénassy-Quéré, Mignon et al., 2005	Cointegration; long-term positive, but negative from 2002 on.	Real Oil → Real USD Causality reversal	China impacts via USD peg and energy-intensive growth	Four country model (Krugman 1980): US, China, OPEC (dollar bloc); EU	1974-2004 (1980-2004)	REER USD; (robustness EUR-USD)	Real market price crude petroleum	Cointegration, VECM Granger test
Krichene, 2005	Cointegration Long- and short-term negative impact	USD → Oil	Purchasing power, local price, channel	Simultaneous equation model (SEM) structural model + interest rates & NEER	1970-2004	NEER USD	IMF crude oil price index	VAR
Yousefi and Wirjanto, 2005	Negative export price elasticity	Real USD → Oil	purchasing power of oil revenues channel	Incomplete FX pass-through Oligopolistic rivalry of OPEC (Bertrand competition)	1989-1999	REER USD index	Monthly spot prices of 4 OPEC members	OLS estimation with standard error correction
Yousefi and Wirjanto, 2004	Negative correlation	USD → Oil	purchasing power of oil revenues Incomplete FX pass-through	Partial market-sharing model. Price leadership Saudi Arabia	1989-1999	REER USD (price adjusted Pmcdi + Pbdi)	WTI, Brent, OPEC + monthly spot prices	Hansen's GMM, Perfect correlation
Amano and van Norden, 1998	Positively cointegrated	Oil → FX	Real oil price capture terms of trade shocks	Single equation error correction model	1972-1992	REER USD	Real WTI	Dynamic simulations.

NEER: Nominal effective exchange rate, REER: Real effective exchange rate, WTI: West Texas Intermediary, VAR: Vector autoregression, VECM: Vector error correction model, OLS: Ordinary least squares.

3. Conditions of the purchasing power channel

As already pointed out, the plausibility of the purchasing power channel hypothesis hinges at least on three conditions: First, oil exporters have some price setting capacity. Second, oil exporters receive a substantial share of their imports from Europe. Third, for good reasons, oil invoicing takes place in US dollar. We will briefly present evidence on each of these three conditions.

3.1 Price setting power

The market for crude oil is often described as a cartel, which at best is an oversimplification (Krugman, 2000[4]). Certainly, members of the OPEC do exert some market power, but the extent of it varies dramatically over time depending on general market conditions. OPEC itself admits that it was price maker until the mid-eighties but maintains that since then prices have been determined at the spot markets on the three big petroleum exchanges in New York (NYMEX), London (IPE) and Singapore (SIMEX)[5]. Indeed, concurrence of declining production with plummeting prices during the early 1980s and the reversal of this behaviour of both time series in the following period does not feature a cartelized market (Yousefi and Wirjanto, 2005). In any case, with soaring demand from China and other emerging economies as well as gradually depleting sources in Non-OPEC oil producing countries OPEC has arguably recaptured some price setting capacity. In 2006 OPEC's 13 member countries represented 55% of world crude oil exports, 45% of world oil production and about 78% of the world's oil reserves.

Perhaps the most accurate way to describe the market as has been undertaken by Yousefi and Wirjanto (2005). They consider a model of oligopolistic rivalry among oil exporting countries with partial sharing of a world oil market segmented by quality differences (sweet vs. sour, heavy vs. light, etc.). In each segment each member country enjoys a certain degree of market power due to non-homogenous commodities (imperfect substitutes). This results in *Bertrand competition* with

[4] Krugman refers to an idea of multiple equilibria developed by Cremer, J. and D. Isfahani (1991). Models of the Oil Market. New York. Harwood Academic Publishers. According to this the fact that oil is an exhaustible resource means that not extracting it is a form of investment.
[5] http://www.opec.org/library/FAQs/aboutOPEC/q20.htm

incomplete price equalization. Saudi Arabia – by far the biggest OPEC oil producer with about one third of OPEC production – displays price leadership.

Other reasons for price setting capacity could be imagined. For instance, oil supply could be split in a competitive and a monopolistic sector. Given very low marginal costs, inelastic total (short-run) demand and inelastic non-OPEC supply due to short-run peak capacity, OPEC cartel should be successful. Oligopolistic behaviour can also be explained by a *kinked demand curve* (Pindyck and Rubinfeld, 2005).

3.2 Asymmetric trade structure

The asymmetry of the trade structure of oil exporting economies results on the one hand from the fact that oil is invoiced in US dollar and on the other hand the geographic patterns of their imports. While the first implies that virtually all exports are going to the *dollar area*, the latter reveals that the US dollar plays only a marginal role with respect to oil exporters' imports. In particular the EU dominates as source region for consumption and investment goods in exchange for petrodollars. The share of the euro area is still somewhat greater than that of Asia[6].

Table 3: Geographical Trading Patterns of 11 major oil exporters 2005[7]

Shares in %				
	USA	**Euro area**	**EU**	**Asia**
Export destinations	13.9	27.4	38.7	25.6
Import sources	6.8	29.2	41.9	25,4

(Source: European Central Bank, 2007)

Eventually, such asymmetry should translate into the terms of trade. Mazraati (2005) calculated that between 1970 and 2004 the loss in purchasing power of OPEC oil revenues through dollar depreciation has been significant (15,6%), although less then the loss through inflation (57,4%). Yet

[6] Note that in this sample Russia and Norway are included, which compared to OPEC have closer ties to the EU than to Asia. According to Mazraati (2005), average import shares of OPEC between 1970 and 2004 have been 28.82% from the euro area and 13.45% from the USA.

[7] Algeria, Iran, Kuwait, Libya, Nigeria, Norway, Russia, Saudi Arabia, UAE and Venezuela.

these two effects are difficult to disentangle as virtually all oil producing economies with undiversified economies and dollar pegged currencies display an inverse relationship between the value of the US dollar and inflation (Alhajji, 2004)

Already in advance to the first oil shock, certain OPEC members and international oil companies could no longer ignore these distortions entailed by the world currency situation. In 1972 they concluded the *Geneva I Agreement* that introduced quarterly adjustments to posted prices to take account of the exchange rate changes. The *Geneva I Index* for crude oil prices used for its calculation the arithmetic average of the deviations of exchange rates of nine currencies against USD[8]. Changed to an import-weighted index, the present *modified Geneva I + US dollar* currency basket accounts for both inflation and currency fluctuations (Organisation of the Petroleum Exporting Countries, 2006). Half of the basket is made up by the euro (46,4%), other currencies included are the US dollar (25,3%), the Japanese yen (15,3%), the UK pound (10,1%) and the Swiss franc (2,8%; Mazraati, 2005).

We take the high weight of the euro in this OPEC basket, reflecting an similarly high share in currency denomination of oil exporters' imports, as justification for simplifying our empirical exercise by using the USD/EUR exchange rate as a proxy to nominal effective exchange rates, .

As the crux of our story, the oil exporters' terms of trade can be represented in the following simple formula:

$$\frac{P^X e^{\$/\$}}{P^M e^{€/\$}}$$

Assume a deterioration of the price level of imports (P^M) by exchange rate depreciation ($e^{€/\$}\downarrow$) in the denominator. Now, the only way to re-establish the terms of trade is to increase export prices ($P^X\uparrow$) in the numerator, given their unalterable denomination in US dollars ($e^{\$/\$}$).

Role of the US dollar

[8] The national currencies of Belgium, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland and the United Kingdom.

But why should denomination in other currencies that fit better to the trading structure not be an easily feasible option? The answer is that oil exporters have to face three interrelated currency choices: Invoicing, recycling and pegging.

First, using one vehicle currency is efficient in terms of minimizing transaction costs and providing price transparency. Invoicing in a single currency is particularly useful in the case of standardized products and volatile prices. The initial decision has possibly to do with reputation and herding behaviour. Once you have chosen a currency it is difficult to abandon it. Mileva and Siegfried (2007) explain the almost universal use of the US dollar in invoicing petroleum[9] as a homogeneous good traded in commodity exchanges. Stability of the US economy and the depth of the US financial markets – and as we would argue, the US dollar/gold standard of the Bretten Woods System – privileged the US dollar as a store of value with low liquidity costs. They suggest, however, that international oil trade is less homogeneous than usually presumed and predominantly regional in nature, indicating that multiple currency oil invoicing might prove to be more likely[10].

Second, however, the choice of invoicing currency goes hand in hand with the not exclusively economic decision on where to save and spend the money earned. In the mid-1970s, the Gulf Cooperation Council (GCC) led by Saudi Arabia was highly influential in ensuring that oil-pricing was set in US dollars[11]. Since then they have supported the value of the US dollar by invoicing oil in dollars and by investing in US dollar reserves and securities. Despite their nervousness about US imbalances and declining value of US dollar reserves, GCC oil exporters are unlikely to undermine the dollar in the short-term as oil future markets increasingly took over command of oil-pricing (Momani, 2006) and they have big stake in the US economy. Nevertheless, GCC states are gradually shifting petrodollar recycling away from US assets to other dollar-denominated investments in Asia and to intraregional investment.

[9] Attempts to shift to euro invoicing have been made by Iran, Iraq and Venezuela.
[10] OPEC Secretary-General Abdullah Al Badri announced in February 2008: “Maybe we can price the oil in the euro. It can be done, but it will take time.” (http://www.gulfnews.com/business/Oil_and_Gas/10188508.html)
[11] In 1975 a preceding US-Saudi deal to recycle Saudi wealth into US bonds was complemented by a subsequent arrangement to invoice oil in US dollars. Saudi Arabia used its OPEC influence to persuade the other members to sell OPEC oil in dollars, in exchange for enhanced power at the IMF and military protection (Momani, 2006).

Third, the first two choices have an impact on the exchange rate regime of oil-exporting countries. Almost all of them have their exchange rates either formally pegged or tightly oriented to the US dollar. In particular, the GCC countries have used the US dollar as the anchor currency since the 1970s (European Central Bank, 2007). They regard dollarization as beneficial given their reliance on the export of a single dollar priced commodity, but also because it lowers financing costs, helps attract foreign investment and supports fiscal as well as macroeconomic stability. More importantly, the choice of the US dollar as a common denominator has been seen as facilitating the transition to a common currency by 2010[12]. Only after its adoption, it may be either anchored to the euro, a currency basket, or let be freely floating (Bank for International Settlements, 2003). However, a decline in the value of US dollars and expansionary monetary policy in the United States adds to the inflationary pressure in the Gulf States already mounting due to soaring oil prices. Additionally, enhanced trade ties with Europe and the envisaged reduction of oil dependence favour a reorientation of their economies away from the dollar toward the euro.

But in the meanwhile the dominant role of the US dollar as invoice, investment and anchor currency seems unchallenged despite the fact that it has pushed oil exporters into a monetary dilemma and in conflict with their own development strategies. As long as feasible alternatives are not in sight[13] the current OPEC strategy of dollarization and oil price stabilization appears rational.

4. The dollar exchange rate and oil prices: a forecasting exercise

In this section we perform a simple forecasting exercise aimed at evaluating whether changes in the US dollar/euro exchange rate contain information about future changes in oil prices. For that purpose we compare the predictions from a simple autoregressive (AR) model on oil price changes with those from a vector autoregressive (VAR) model including changes in the exchange rate, its determinants and oil prices, as well as a vector error correction (VEC) model for these variables. In the case of the

[12] A currency union is seen an instrument to integrate and to diversify the economies of the region. The decicsion to establish a common currency has already been taken at the foundation of the GCC in 1981. The official adoption of the US dollar as a common basis has been agreed in 2001.

[13] Frankel (2006) proposed a peg to oil export prices, which would possibly exacerbate volatility. Mundell (2002) proposed invoicing in Special Drawing rights.

VAR and VEC models, the specification can be interpreted as a monetary model of exchange rate determination augmented with an oil price variable (see for example Frenkel, 1976, Meese and Rogoff, 1983, MacDonald and Taylor, 1992 and 1994) where the exchange rate is assumed to be determined by changes in the relative money supply, output and interest rate changes of the US and the euro area. The two competing models are thus given by the following specifications,

$$\Delta p_t = \phi_0 + \sum_{k=1}^{p} \phi_k \Delta p_{t-k} + \varepsilon_t , \qquad (1)$$

and

$$\Delta \mathbf{v}_t = \Theta_0 + \sum_{k=1}^{p} \Theta_k \Delta \mathbf{v}_{t-k} + \mathbf{u}_t , \qquad (2)$$

where $\mathbf{v}_t$=(p_t e_t m_t y_t i_t)', p_t=ln(p_t), e_t=ln(e_t), m_t=ln($M_{t,US}$/ $M_{t,EUR}$), y_t=ln($Y_{t,US}$/ $Y_{t,EUR}$), i_t=($r_{t,US}$- $r_{t,EUR}$) and e_t=ln(e_t), where p_t is the oil price, M_t is money supply, Y_t is output, r_t is the interest rate and e_t is the nominal US$/EUR exchange rate. Θ_0 is a 5-dimensional vector of intercept terms and Θ_k are 5×5 matrices of parameters. The error term ε_t is assumed to be a white noise process with constant variance σ^2, and $\mathbf{u}_t$ = (u_{1t} u_{2t} u_{3t} u_{4t} u_{5t})' is assumed to be an iid vector process with zero mean and constant variance-covariance matrix Σ.

Since there is evidence of a unit root for all variables in the vector **v**, a potential specification relating these variables would be a vector error correction (VEC) model, where there is an adjustment in the long run to a cointegration relationship given by a linear function relating the covariates of the model,

$$\Delta \mathbf{v}_t = \Gamma_0 + \sum_{k=1}^{p} \Gamma_k \Delta \mathbf{v}_{t-k} + \alpha\beta' \mathbf{v}_{t-1} + \mathbf{u}_t , \qquad (3)$$

where the β is the (column) cointegrating vector, which defines the long-un equilibrium among the variables of the system, given by $\beta'\mathbf{v}_t$, and α is a (column) vector capturing the adjustment speed of each one of the components of $\mathbf{v}_t$.

The forecasting exercise is carried out as follows. The models given by (1), (2) and (3) are estimated using monthly data from January 1983 to December 1996,[14] choosing the optimal lag length (p in the specifications above) by minimizing the Bayesian information criterion (BIC) for lag lengths one to twelve. With the estimated models, out-of-sample forecasts for the oil price are produced for forecasting horizons ranging from one month ahead to three years (36 months) ahead. Measures of forecasting error are computed for the predictions using the actually realized oil prices at the different forecasting horizons. The observation corresponding to January 1997 is added to the estimation sample, the models are re-estimated (after choosing a potentially new optimal lag length) and the procedure described above is repeated for this new in-sample period. This procedure is iterated until no usable out-of-sample observations are left.

We compute two measures of forecasting accuracy:

a) The root mean squared error (RMSE), given by

$$RMSE(h) = \sqrt{\frac{1}{N}\sum_{n=T+h}^{T+h+N}\left(p_n^h - p_n\right)^2} \quad (4)$$

where p_t^h is the forecast for p_t obtained by the model with data ranging up to t-h, and N is the number of out-of-sample forecasts carried out. Root mean squared errors are computed for forecasting horizons (h), ranging from one month ahead to 36 months ahead.

b) The direction of change (DOC) statistic, defined as the number of correctly forecast changes in the oil price for forecasting horizon h divided by the total size of the forecasting sample for that forecasting horizon. This measure describes the ability of the model in forecasting the direction of change of the oil price correctly.

If two models deliver forecasts of different quality (as measured for instance by the RMSE), the question arises if the "better" model performs *significantly* better than the "worse" model in statistical terms. In order to evaluate the statistical significance of differences in RMSE, we compute the

- [14] The source of the oil price data is the EIA and the rest of the variables are obtained from DATASTREAM.

Diebold-Mariano test. The Diebold-Mariano test (Diebold and Mariano, 1995 henceforth, DM) is an asymptotic test for the null of equal predictive accuracy of two models. For a given forecasting horizon *h*, the null hypothesis in the DM test is that

$$d_n = E\left[g(e_{1n}) - g(e_{2n})\right] = 0, \tag{5}$$

where e_{1n} is the forecasting error produced by model 1 when forecasting p_t, e_{2n} is defined analogously for model 2 and $g(z)$ is a loss function associated to the forecast error. In our case, the loss function is a quadratic one, so that $g(z)=z^2$. The DM test is based on the observed average forecast error difference, $\overline{d}$. The DM test statistic is given by

$$S_1 = [\hat{V}(\overline{d})]^{-1/2}\,\overline{d}\ . \tag{6}$$

$\hat{V}(\overline{d})$ is an estimate of the asymptotic variance of $\overline{d}$, given by

$$\hat{V}(\overline{d}) = \frac{1}{N}\left(\hat{\gamma}_0 + 2\sum_{k=1}^{h-1}\hat{\gamma}_k\right), \tag{7}$$

where $\hat{\gamma}_k$ is the *k*-th order sample autocovariance of the forecasting error difference series. The asymptotic distribution of S_1 is standard normal, so tests for equality of predictive accuracy between different models can be easily carried out. Although the DM test has become standard in forecasting evaluation research, this test methodology is not free of criticism. For a recent critical assessment to testing predictive accuracy using the DM test statistic (Kunst, 2003).

In a preliminary analysis, we ran Granger causality tests between changes in the exchange rate and the oil price in the framework of a bivariate VAR in first differences, in order to grasp the existing causality links between these two variables. The results are relatively inconclusive in this respect: there is marginal evidence of causality running from the exchange rate to the oil price if VAR models of lag length higher than six are used. However, the optimal lag length for the bivariate VAR model as chosen by the BIC for the complete sample is equal to one. At this lag length it cannot be rejected that there are no causality links between the two variables.[15]

Table 4 presents the results of the forecasting exercise described above. The results corresponding to the best models in terms of forecasting accuracy are presented in bold characters. For each forecasting horizon in which the VAR and/or VEC model performs better than the benchmark AR model we carried out a DM test for equal forecasting accuracy and the result in terms of significance is presented in the table in the form of asterisks. Some interesting results can be read from Table 4. In terms of RMSE, models including information on the exchange rate and its determinants perform better than the benchmark AR model for forecasting horizons up to one year ahead and over 18 months ahead. For short-term forecasts the VAR model, which abstracts away from the existence of a long-run relationship linking the variables in the VAR structure, is the specification that performs best, obtaining forecasts which are significantly better than the benchmark model (as measured by the DM test statistic) in forecasting horizons ranging up to 6 months ahead. The VEC model performs best for relatively long forecasting horizons, and obtains significantly better forecasts than the AR benchmark at forecasting horizons of more than two and a half years ahead.

The results concerning the DOC statistic speak clearly for the inclusion of information on the exchange rate when forecasting oil prices. The best performing model according to this criterion is the VAR model for relatively short forecasting horizons (up to nine months ahead) and the VEC model for longer forecasting horizons. The supremacy of the models including information on the exchange rate and its determinants when forecasting the direction of change of the oil price is systematic and robust for all forecasting horizons considered.

As a robustness check we also performed the forecasting exercise using exclusively bivariate time series models formed by the oil price and the exchange rate, that is, without controlling for the potential determinants of the exchange rate. The results of this exercise are presented in Table 5, and they reinforce those found with the larger vector autoregressive models.

[15] Detailed results of the causality analysis are available from the authors upon request.

Table 4: Results of the forecasting exercise: multivariate time series models.

Months ahead	AR model		VAR model		VEC model		# Out of sample observations
	RMSE	DOC	RMSE	DOC	RMSE	DOC	
1	0.084	0.472	**0.082***	**0.509**	0.084	0.491	108
3	0.164	0.453	**0.152***	**0.528**	0.171	0.481	106
6	0.242	0.379	**0.223***	**0.515**	0.265	0.447	103
9	0.307	0.410	**0.295**	**0.490**	0.345	**0.490**	100
12	0.370	0.371	**0.365**	0.392	0.407	**0.474**	97
15	**0.428**	0.362	0.428	0.340	0.451	**0.511**	94
18	**0.466**	0.418	0.471	0.308	0.478	**0.516**	91
21	0.494	0.398	0.505	0.284	**0.491**	**0.523**	88
24	0.516	0.388	0.532	0.165	**0.492**	**0.565**	85
27	0.522	0.383	0.540	0.198	**0.483**	**0.617**	82
30	0.532	0.316	0.551	0.139	**0.483**	**0.544**	79
33	0.547	0.250	0.562	0.145	**0.482***	**0.539**	76
36	0.569	0.151	0.581	0.123	**0.486****	**0.493**	73

Asterisks refer to the significance level of the Diebold-Mariano test statistic of the corresponding model against the AR model. * (**) refers to significance at the 10% (5%) significance level. Best models for each forecasting horizon are in bod font.

Table 5: Results of the forecasting exercise: bivariate time series models.

Months ahead	AR model		VAR model		VEC model		# Out of sample observations
	RMSE	DOC	RMSE	DOC	RMSE	DOC	
1	0.084	0.472	**0.081***	**0.528**	0.084	0.472	108
3	0.164	0.453	**0.151***	**0.566**	0.176	0.519	106
6	0.242	0.379	**0.219**	**0.563**	0.280	0.437	103
9	0.307	0.41	**0.291**	**0.550**	0.365	0.480	100
12	0.37	0.371	**0.360**	0.433	0.423	**0.464**	97
15	0.428	0.362	**0.421**	0.362	0.461	**0.500**	94
18	0.466	0.418	**0.462**	0.352	0.483	**0.505**	91
21	0.494	0.398	0.495	0.318	**0.490**	**0.534**	88
24	0.516	0.388	0.521	0.224	**0.486**	**0.576**	85
27	0.522	0.383	0.527	0.235	**0.474**	**0.630**	82
30	0.532	0.316	0.537	0.215	**0.473**	**0.544**	79
33	0.547	0.25	0.547	0.197	**0.470***	**0.539**	76
36	0.569	0.151	0.565	0.164	**0.473****	**0.493**	73

Asterisks refer to the significance level of the Diebold-Mariano test statistic of the corresponding model against the AR model. * (**) refers to significance at the 10% (5%) significance level. Best models for each forecasting horizon are in bod font.

In the short run, the VAR model including the exchange rate forecasts significantly better than the simple autoregressive benchmark, while in the long run it is the VEC model with the exchange rate and the oil price which significantly beats the other alternative specifications. These results offer thus extra evidence concerning the fact that the US dollar/euro exchange rate contains information about the future development of oil prices.

5. Concluding remarks

Building on the stabilization of the import purchasing power of oil exporter revenues, we elaborate a simple explanation linking exchange rates of the US dollar to the oil price. While, based on Granger-causality tests, the direction of causality is unclear; we show that exchange rate information improves oil price forecasts significantly. Our results do not exclude that other channels may also be at work, such as demand shifts owing to local price changes, monetary policy and asset or currency markets.

The implications of our results can be stated in form of pertinent questions rather than answers. Given the vulnerability of oil prices to monetary shocks, should Taylor-like rules explicitly include crude price volatility (see Krichene, 2005)? To what extend is a stable US dollar a prerequisite for stable oil prices? Would exchange rate flexibility of oil exporters be a remedy or an amplifier of global imbalances? How will a hard landing scenario of the US dollar have an effect on oil prices? Is there an alternative of the US dollar as invoicing, reserve and anchor currency? How best should an orderly replacement be managed? And will with euro, yuan or basket denominated oil the stagflationary effects of oil price shocks be reduced (Wohltmann and Winkler, 2005)?

Future research should concentrate on exploring non-linearity and asymmetries in the relation. Robustness should also be checked in terms of alternative oil data sets, diverse frequency or trade weighted exchange rates. Making an explicit distinction between supply and demand shocks may also shed a light on the nature of the relationship.

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