Crude Oil Prices and the USD/EUR Exchange Rate

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This paper investigates the impact of changes in the U.S. dollar/euro exchange rate on crude oil prices. The negative correlation of these two variables is ascribed to five possible channels: on the supply side, the purchasing power of oil export revenues and on the demand side, local prices in non-U.S. dollar regions, investments in crude oil-related asset markets, the monetary policy regime in oil-exporting countries and the efficiency of the currency market. We give evidence that using information on the U.S. dollar/euro exchange rate (and its determinants) significantly improves oil price forecasts. We discuss the possible implications these results might suggest with regard to the stabilization of oil prices or the adjustment of global imbalances.

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Due to the recent oil price shock, economists have increasingly devoted their efforts to the analysis of energy markets. Similarly, the continuous build-up of global imbalances keeps raising economists' interest in 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 a coincidence that crude oil prices have been soaring while, simultaneously, the U.S. dollar has depreciated to reach a record low (and vice versa)?

In this study we analyze the information content of the USD/EUR exchange rate for forecasting oil prices, using monthly data from 1983 to 2006. In particular, we analyze whether including information on the exchange rate and its determinants in simple time series models of the oil price improves the models' predictive power. The effects found here may also be reflecting indirect effects of other economic variables which are captured through the evolution of the exchange rate.

Five possible channels of the negative relation between the U.S. dollar and crude oil prices can be put forward: a purchasing power channel, a local price channel, an investment channel, a monetary policy channel and a currency market channel. These five channels can be derived from the following five hypotheses: First, oil-exporting countries aim to stabilize the purchasing power of their (U.S. dollar) export revenues in terms of their (predominately euro-denominated and not U.S. dollar-denominated) imports. Second, the U.S. dollar's depreciation makes oil less expensive for consumers in non-U.S. dollar regions (in local currency), thereby increasing their crude oil demand, which eventually causes adjustments in the oil price denominated in U.S. dollars. Third, a falling U.S. dollar reduces the returns on U.S. dollar-denominated financial assets in foreign currencies, increasing the attractiveness of oil and other commodities as a

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class of alternative assets to foreign investors. Commodity assets also serve as a hedge against inflation, since the U.S. dollar's depreciation raises the risk of inflationary pressures in the United States. Fourth, the U.S. dollar's depreciation entails monetary easing elsewhere, including in oil-producing countries with currencies pegged to the U.S. dollar. In turn, lower interest rates increase liquidity, thereby stimulating demand, including demand for oil. Fifth, foreign exchange markets are possibly more efficient than oil markets and hence anticipate developments in the real economy that affect the demand for and supply of oil.

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 hotly debated issue, for instance, is the contribution of oil-exporting countries to persistent global imbalances. The surge in oil prices since the end of the 1990s has led to rising current account surpluses of oil-exporting countries that outpace those of Asian emerging economies and whose levels correspond to a large extent to U.S. current account deficits. As a consequence, the U.S. Treasury suggested that *"oil exporters should consider the role that the choice of foreign exchange regime can play in the adjustment process"* (McCown et al., 2006). 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 than the U.S.A. (e.g. Ruiz-Perez and Vilarrubia, 2006) and diversify their investment away from U.S. dollar-denominated assets (BIS, 2006), it is not obvious that this recommendation will have an impact. 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 price shock on European growth (European Commission, 2006). Furthermore, the impact of oil prices on Europe has already been moderated by the appreciation of its currencies – in particular of the euro – vis-à-vis the U.S. dollar. All in all, this did not sufficiently curb European oil demand; oil prices continued to rise and contributed further to unbalanced current account deficits in the U.S.A.

This contribution is also related to the research agenda on the connection 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 nexus 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 can be seen as an extension to the approach on non-commodity currencies adopted by Chen et al. (2008), while at the same time presenting complementary explanations to that approach.

This paper is organized as follows. Section 1 shows some stylized facts about the historical development of the main bilateral exchange rates to the U.S. dollar and of crude oil prices. Section 2 introduces a review of the theoretical and empirical literature on the link between these variables and discusses the five hypotheses on the presumed negative (causal) relationship between exchange rates and oil markets. In section 3 we present our forecasting exercise; section 4 concludes.

1 A Short Contemporary History of Oil Prices and the U.S. Dollar Exchange Rate

In post-war economic history (1950 to 2007) we can roughly distinguish four periods in the relationship between oil prices and the (synthetic) USD/EUR exchange rate. Chart 1 shows annual time series of U.S. crude oil import prices and nominal USD/EUR exchange rates (a synthetic euro is used for the period prior to 1999 while for the period prior to 1978, the Deutsche mark is converted into synthetic euro).

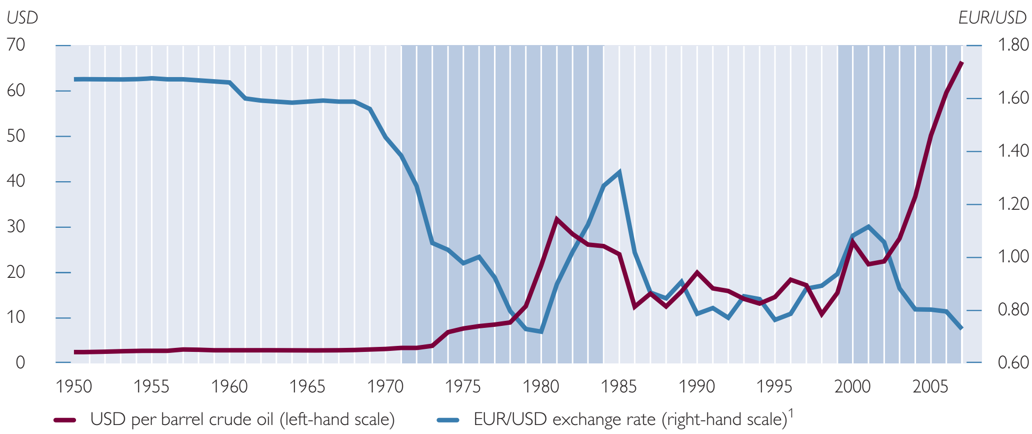
The four different periods are easily discernable by the two variables' varying volatility and their degree of co-movement. Interestingly, these periods coincide with important regime shifts in both oil and money markets. The distinction of the periods is also reflected by changing correlations between crude oil prices and nominal USD/EUR exchange rates (table 1). While the whole sample of data yields a correlation coefficient of –0.64, both sign and size of this correlation vary quite substantially across the four different periods – a result which is also confirmed by rolling correlation exercises.

The first period under observation (1950 to 1970) coincides with the Bretton Woods system of fixed exchange rates, which was introduced in 1946. The commitment to maintain a fixed conversion rate of the U.S. dollar to gold created a *world dollar standard* (McKinnon, 2005), i.e. all other exchange rates were 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. the seven international 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 price shocks of 1973 and

Chart 1

USD Exchange Rate and Crude Oil Prices 1950 to 2007 (annual change)



Source: EIA, BIS, Bloomberg, www.history.ucsb.edu.

[1] *Before 1978: synthetic EUR values (converted DEM).*

Table 1

Four Periods of Correlation between U.S. Dollar Exchange Rates 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	1999 to 2007	Emerging market demand and tight supply	high	–0.80

Source: OeNB.

1979, respectively. The so-called *Nixon shock* (e.g. Kuroda, 2004) had occurred on August 15, 1971, i.e. even before the first oil price shock, when U.S. president Richard Nixon announced the discontinuation of gold convertibility of the U.S. dollar given the deteriorating U.S. balance of payments. This move resulted in a steep depreciation of the value of the U.S. dollar against gold and many other currencies, notably the Deutsche mark and the Japanese yen. Since oil was invoiced in U.S. dollars, this implied that oil producers were receiving fewer revenues at the same price of oil. The Organization of the Oil Exporting Countries (OPEC) was initially slow in adjusting oil prices to reflect the U.S. dollar's depreciation. Only two years later, during the Yom Kippur War, OPEC cut its oil production and placed an embargo on shipments of crude oil to the West. As a result the oil price had quadrupled by 1974, reaching USD 12 per barrel. The second oil crisis occurred in the wake of the Iranian Revolution, which temporarily shattered oil production in the country. The subsequent market panic and a phased decontrol of oil prices by the Carter administration triggered another boost of crude oil prices over the next 12 months, with prices going up to almost USD 40 per barrel. Subsequently, oil prices moderated slightly despite the ongoing *war between Iran and Iraq*, but remained at a high level. In parallel, the U.S. 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 System, Paul Volcker, successfully trimmed down inflation by more than 10 percentage points in two years – a measure which entailed a significant recession, however. The negative correlation between the U.S. dollar exchange rate and the crude oil price can be observed until 1985.

Between 1985 and 1998 the correlation between U.S. dollar exchange rates and oil prices diminished in absolute terms, while both remained remarkably stable (Krichene, 2006). This period was characterized by the collapse of the oil price and a weak U.S. dollar following the *Plaza Accord* concluded by five G-7 countries. Important changes took place in the OPEC which affected its power to exert influence on the oil market. In August 1985, Saudi Arabia gave up its swing producer strategy (which had involved occasional production cuts in order to stem price decreases), linking its oil prices to the spot market for crude oil and more than doubling its extraction quantity instead. By mid-1986, crude oil prices had dropped to around USD 10 per barrel. From then until 1998, oil prices remained weak and OPEC's attempts to set price targets failed, not least because rapidly growing spot, forward and futures markets brought about greater price transparency and independence of oil importing countries from the alleged cartel.

In September 1985, the *Plaza Accord* was signed with the aim of devaluing the U.S. dollar in relation to the Japanese yen and Deutsche mark in order to help the U.S.A. reduce its current account deficit and emerge from a serious recession. Over the following two years, coordinated central bank intervention in currency markets caused a depreciation of the U.S. dollar against the Japanese yen by more than 50%. The decline of the U.S. dollar exchange rate was slowed by the *Louvre Accord*, signed by six G-7 countries in 1987, but the U.S. currency did not recuperate until the middle of the next decade.

The price of crude oil surged temporarily in 1990 during the Iraqi occupation of Kuwait, but after the subsequent *Gulf War* crude oil prices declined almost uninterruptedly, partly squeezed by transition-induced recession in the former Soviet Union and in Central and Eastern Europe (Borensztein and Reinhart, 1994), reaching their deepest level throughout the Asian Crisis of 1997 and 1998.

The last period under review, i.e. the period from 1999 to 2007,[2] is marked by an oil price pickup which has been triggered by increasing demand from emerging markets (in particular from China). Both the failure of oil producers to anticipate the fast rebound of the Asian economies and the low levels of exploration investment due to low crude oil prices in the 1990s led to insufficient supplies. Future supply, however, increasingly became a major matter of concern, as global crude oil production did not amplified for two years in a row and excess demand could only be met by natural gas liquids (NGL). Given the fact that non-OPEC production is already beyond its peak, the only hope for meeting increasing demand rests on the oil production by OPEC countries. The fact that these countries are politically instable added to the apprehension about future oil supply. Being in the comfortable position of a producer of last resort, the OPEC is experiencing a revival of some of its market power, as announced production cuts have now again been at least partly effective. Actual and expected oil market fundamentals,[3] geopolitical tensions as well as financial turmoil – not least due to excess liquidity – have given rise to financial speculation, which in turn has contributed to an *overshooting* oil market.

At the beginning of the last period, the U.S. dollar was supported by the booming U.S. economy. However, from around 2002 onward – after a short interruption of the oil price hike[4] – the relation between the U.S. dollar exchange rate and oil prices has once again become clearly negative. Accumulating U.S. external imbalances have built up pressure on the U.S. dollar, and the situation has been aggravated by mounting interest rate differentials in comparison to the euro area. Very recently, however, both the U.S. dollar decline and the oil prices hike have

[2] *From the present point of view, this period lasted until mid-2008.*

[3] *Additionally, crude oil prices may have been driven by many other factors. As for refining capacity, it should be noticed that unlike common believe the relationship to oil prices is negative such that higher refinery utilization rates reduce crude oil prices. This effect arises from shifts in the production of heavy and light grades of crude oil, leading to changes in price spreads between them and depending on the composition of demand as well as the technical requirements of refining (Kaufmann et al., 2008).*

[4] *This interruption would justify dividing the last period into two shock phases.*

been partially reversed, as it became evident, that Europe and the rest of the world would not be able to decouple from the economic slump in the United States.

As this short overview suggests, any meaningful interpretation of data behavior has to take into account geopolitical and historical economic events. Notwithstanding the difficulties of abstracting from these facts, some theories of a more general nature have already been put forward.

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 numeraire. With the gold-dollar standard in place, it was logical to price and quote homogenous goods like commodities in U.S. dollars. Later, under a flexible exchange rate regime, markets continued to stick to the U.S. dollar, partly because having only one reference and vehicle currency is efficient. Yet, the extreme instability of the external value of the U.S. dollar has translated into U.S. dollar prices of commodities such as crude oil. The underlying causes of this apparent link between the commodity price cycle and the U.S. dollar cycle, however, are controversial. These cycles may mutually affect each other or be both caused by common factors. Depending on the channel highlighted by the respective theory, the link may either be positive or negative or may change from one period to the other. Five possible channels of a negative causal relation between the external value of the U.S. dollar and crude oil prices can be put forward (e.g. Cheng, 2008).

2.1 Purchasing Power Channel

To the extent that oil-exporting countries aim to stabilize the purchasing power of their (U.S. dollar) export revenues in terms of their (predominantly euro-denominated) imports, changes in the U.S. dollar/euro (USD/EUR) exchange rate may be mirrored in oil exporters' pricing behavior[5] (Amuzegar, 1978). Following up on the role of the U.S. dollar as a numeraire of standard commodities *(U.S. dollar commodities)*, a change in U.S. 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 "non-U.S. dollar goods" in these countries' trade structure (Schulmeister, 2000). Since the difference between the export and import share of dollar goods is greatest for oil-exporting countries, their income position is most strongly affected by U.S. dollar exchange rate fluctuations. Hence, they have an incentive to react to U.S. dollar depreciation by increasing export prices.[6]

The plausibility of this *purchasing power channel* hinges on at least three conditions: First, oil exporters have a certain degree of price-setting capacity. Second, oil exporters receive a substantial share of their imports from Europe

[5] *Although it is often the case that the literature refers to the price-setting behavior of oil exporters, it should be noted that the OPEC, as of 1986, has not tried to set prices directly, but followed a quantity strategy which indirectly influenced the market clearing price.*

[6] *Note that their reaction might be asymmetric, as they tend to tolerate the U.S. dollar's appreciation rather than depreciation.*

(in particular from euro area countries). Third, for good reasons, oil invoicing is conducted in U.S. dollars. We will briefly examine evidence on each of these three conditions.

As to the first condition, the market for crude oil is often described as a cartel, which is at best an oversimplification (Krugman, 2000).[7] Indeed, the concurrence of declining production with plummeting prices during the early 1980s and the subsequent reversal of this behavior in both time series are not characteristic of a cartelized market (Yousefi and Wirjanto, 2005). Certainly, members of the OPEC do exert some market power, but the extent of it varies dramatically over time depending on general market conditions. With soaring demand from China and other emerging economies as well as gradually depleting sources in non-OPEC oil-producing countries, OPEC has arguably regained some price-setting capacity. In 2006 OPEC's 13 member countries accounted for 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 has been undertaken by Yousefi and Wirjanto (2005). They consider a model of oligopolistic rivalry among oil-exporting countries with a 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 incomplete price equalization and Saudi Arabia – by far the biggest OPEC oil producer with about one-third of OPEC production – displaying price leadership.

As to the second condition, the asymmetry of the trade structure of oil-exporting economies is presented in table 2. While the fact that oil is invoiced in U.S. dollars first implies that virtually all exports are going to the *U.S. dollar area*, the U.S. dollar plays only a marginal role with respect to oil exporters' imports. In particular the EU (and the euro area) is the most important source region for consumption and investment goods in exchange for *petrodollars*.[8]

Table 2

Geographical Trading Patterns of Ten Major Oil Exporters (2005)[1]

	U.S.A.	Euro area	EU	Asia
	Share in %			
Export destinations	13.9	27.4	38.7	25.6
Import sources	6.8	29.2	41.9	25.4

Source: ECB (2007).

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

[7] *Krugman (2000) refers to an idea of multiple equilibria developed by Cremer and Isfahani (1991). According to this, the fact that oil is an exhaustible resource means that not extracting it is a form of investment. For a different explanation, see Rauscher (1992).*

[8] *Note that in this sample Russia and Norway are included, which compared to OPEC have even 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 U.S.A.*

Eventually, such asymmetry should translate into the terms of trade.[9] Already in 1972 certain OPEC members and international oil companies concluded the *Geneva I Agreement*, which introduced quarterly adjustments to posted prices to take account of exchange rate changes. They set up an index which later has changed to an import-weighted index, the *present modified Geneva I + U.S. dollar* currency basket, which accounts for both inflation and currency fluctuations (OPEC, 2006).[10] Half of this basket is made up by the euro (46.4%; Mazraati, 2005).

We take this high weight as justification for simplifying our empirical exercise by using the USD/EUR exchange rate as a proxy to nominal effective exchange rates. Over time, however, the share of the euro area within all OPEC imports has decreased, as shown in chart 3, in favor of developing and emerging economies.

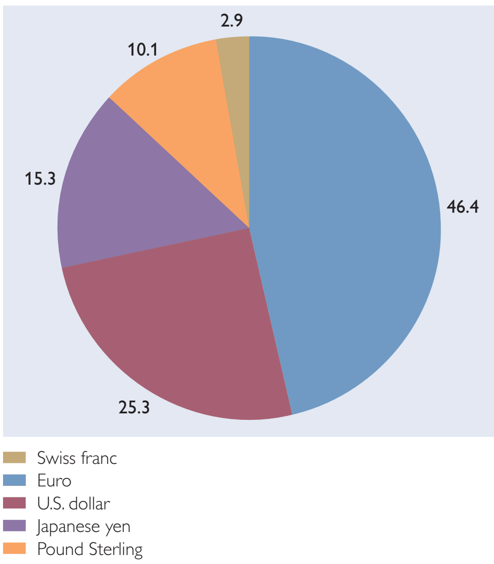
As to the third condition, oil exporters face three interrelated currency choices: invoicing, recycling of oil revenues and pegging. Mileva and Siegfried (2007) explain the almost universal use of the U.S. dollar in invoicing[11] petroleum by the fact that oil is a homogeneous good traded in commodity exchanges. The initial decision to invoice in U.S. dollars has possibly to do with the U.S.A.'s reputation of a stable economy and the depth of its financial markets, but is also built on political grounds. In the mid-1970s, Saudi Arabia was highly influential in ensuring that oil-prices were set in U.S. dollars.[12] Since then, the latter member states of the Gulf Cooperation Council (GCC) have supported the value of the U.S. dollar by invoicing oil in U.S. dollars and by investing in U.S. dollar reserves and securities. Despite their nervousness about U.S. imbalances and the declining value of U.S. dollar

Chart 2

Geneva I + USD Currency Basket 1998 to 2002

Shares of currencies (reflecting import weights)

%



Source: Mazraati (2005).

[9] *Mazraati (2005) calculated that between 1970 and 2004 the loss in purchasing power of OPEC oil revenues through the U.S. dollar's depreciation had been significant (–15.6%), but smaller than the loss through inflation (–57.4%). Yet these two effects are difficult to disentangle as virtually all oil-producing economies with undiversified economies and U.S. dollar-pegged currencies display an inverse relationship between the value of the U.S. dollar and inflation (Alhajji, 2004).*

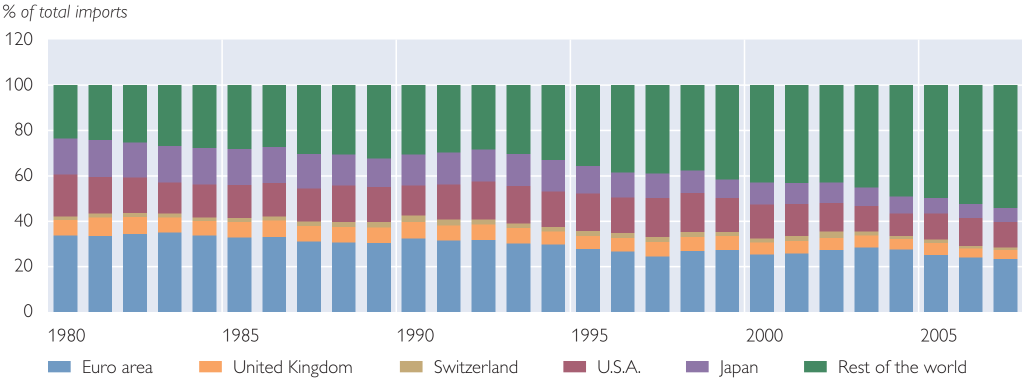
[10] *Indeed, for some time OPEC used currency variations in the Geneva basket to justify oil price increases; although it is unclear to what extend this actually played a role.*

[11] *Attempts to shift to euro invoicing have been made by Iran, Iraq and Venezuela.*

[12] *In 1975 a U.S.-Saudi deal to recycle Saudi wealth into U.S. bonds was complemented by a subsequent arrangement to invoice oil in U.S. dollars. Saudi Arabia used its OPEC influence to persuade the other members to sell OPEC oil in U.S. dollars, in exchange for enhanced power in the IMF and military protection (Momani, 2006).*

Chart 3

Shares in OPEC Imports (without intra-OPEC Trade)



Source: IMF.

reserves, GCC oil exporters have a big stake in the U.S. economy (Momani, 2006). Almost all oil-exporting countries, and in particular, the GCC countries have their exchange rates either formally pegged or tightly oriented to the U.S. dollar (ECB, 2007). They regard dollarization as beneficial given their reliance on the export of a single U.S. dollar-priced commodity, but also because it may lower financing costs, help attract foreign investment and support macroeconomic stability.[13] However, a decline in the value of U.S. dollars and expansionary monetary policy in the United States adds to the inflationary pressure in oil-exporting countries already mounting due to soaring oil prices. Additionally, enhanced trade ties with Europe and the envisaged reduction of oil dependence speak in favor of a reorientation of their economies away from the U.S. dollar toward the euro.[14] Nevertheless, the dominant role of the U.S. dollar as invoice, investment and anchor currency seems to be unchallenged so far 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,[15] the current OPEC strategy of dollarization and oil price stabilization proves reasonable.

2.2 Local Price Channel

Apart from the described supply-side *purchasing power channel*,[16] there is arguably also a demand-side *local price channel* at work. According to Austvik (1987), fluctuations in the exchange rate of the U.S. dollar create disequi-

[13] *Furthermore, dollarization facilitates the transition of the GCC countries into a currency union by 2010, which is to be an instrument to integrate and to diversify the economies of the region. The decision to establish a common currency was taken at the foundation of the GCC in 1981. The official adoption of the U.S. dollar as a common basis was agreed in 2001. Only after its actual introduction, the new currency may be either anchored to the euro, a currency basket, or floating freely (BIS, 2003).*

[14] *OPEC Secretary-General Abdalla El-Badri announced recently, "Maybe we can price the oil in the euro. It can be done, but it will take time." (www.gulfnews.com/business/Oil_and_Gas/10188508.html; published on February 9, 2008).*

[15] *Frankel (2006) proposed a peg to oil export prices, which would possibly exacerbate volatility. Mundell (2002) proposed invoicing in special drawing rights.*

[16] *Note that Alhajji (2004) also observes that the U.S. dollar's depreciation reduces activities in drilling activities in Europe and the Middle East.*

libria in the market for crude oil. The U.S. dollar's depreciation makes petrol less expensive for consumers in non-U.S. dollar regions (in local currency), thereby increasing their commodity demand, which eventually causes adjustments in the oil price denominated in U.S. dollars. Using annual BP data from between 1965 and 2007, we discover as a first indication of this channel a highly negative correlation (–0.81) between European demand for oil products and the USD/EUR exchange rate.

2.3 Investment Channel

In addition, an *asset channel* is put in motion, as a falling U.S. dollar reduces the returns on U.S. 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. Furthermore their attractiveness as a hedge against inflation rises too, since the U.S. dollar's depreciation raises risks of inflationary pressures in the United States. This is reminiscent of the topical debate over the extent to which contemporary oil price developments are driven by market speculation rather than fundamentals. Krugman (2008) speaks about an "oil nonbubble." He argues that "the only way speculation can have a persistent effect on oil prices is if it leads to physical hoarding," which he cannot discern. Yet, Stevans and Sessions (2008) counter, "(…) there is empirical evidence of hoarding in the crude oil market: both oil stocks and futures prices are positively correlated with each other." The debate is not concluded yet, not least because it is difficult to distinguish between speculation, which exploits rather short-term volatility, and hedging activity with the aim of diversifying portfolios, insuring oil-dependent industries against price-related risks and making use of the presumed anti-cyclical performance of commodity futures. In the context of this study it is only important to note that activity in West Texas Intermediate (WTI) future contracts has grown strikingly since 2000. Between January 2004 and June 2008 the number of open interest contracts across all relevant contract types traded on the New York Mercantile Exchange (NYMEX) alone more than tripled from around 900,000 to more than 2.9 million. Yet empirical evidence suggests that the causality goes rather from oil future price changes to changes in contract positions than the reverse (ITF, 2008).

2.4 Monetary Policy Channel

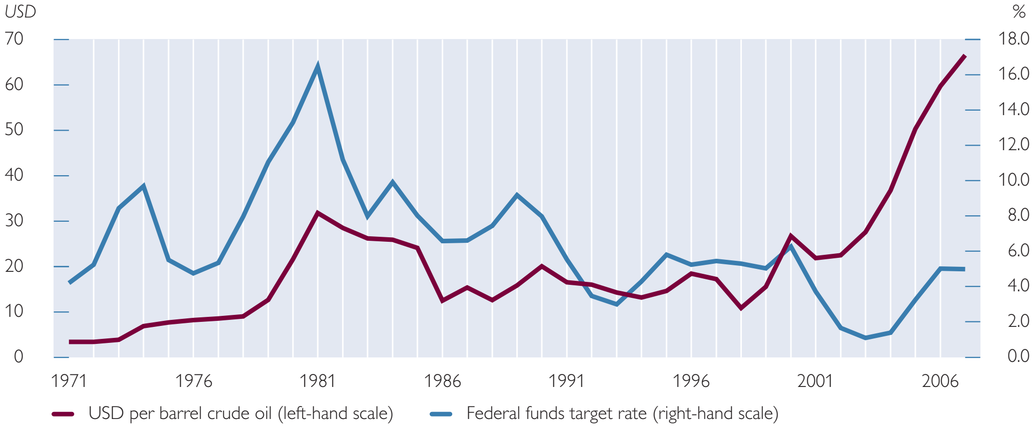
Co-movements could also evolve by a *monetary channel*, as the U.S. dollar's depreciation entails monetary easing elsewhere, including oil-producing countries with currencies pegged to the U.S. dollar. In turn, lower interest rates increase liquidity, thereby stimulating demand, together with that for oil (Cheng, 2008). This channel is evidenced by the fact that currently most of the growth in global crude oil demand comes from China and the Middle East, both known for having their currencies anchored to the U.S. dollar. Similarly, one could argue that both relative price developments (oil price and exchange rate) may have common causes. Most prominently, the hypotheses that 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 a rationalization.

2.5 Currency Market Channel

Finally, a *currency market channel* may be at work as well, since foreign exchange

Chart 4

USD Federal Funds Rate and Crude Oil Price 1971 to 2007 (annual change)



Source: EIA, Thomson Reuters.

markets are possibly more efficient than oil markets and hence anticipate developments in the real economy that affect the demand for and supply of oil (Chen et al., 2008). The causality of this last channel appears to go from the U.S. dollar to oil prices, while it is actually underlying a relation which runs in the opposite direction. In this sense, hypotheses on a negative relation in which oil impacts the U.S. dollar might complement rather than substitute the hypotheses on a reverse direction of causality from the U.S. dollar to oil, which we prefer here.

One of the above-mentioned channels may dominate the relationship, which does not exclude the influence of even (temporarily) contradictory forces. Krugman (1980), for instance, proposed a three-country 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 U.S. dollar assets, but it might turn negative in the long run since over time OPEC's spending on manufactured products rises, and preferably these imports come from other countries than the United States. 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 of the reversed causality.

Ultimately the question concerning which one of these channels dominates should be approached empirically. Table 3 collects the most relevant pieces of the empirical literature on the exchange rate-oil price link; they display a great variety of estimation results due to differences in theoretical concepts, data definition and temporal delimitation.[17] Over time, the negative relation between the U.S. dollar and the oil price, driven by the exchange

[17] *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. Real exchange rates, which are sometimes used as well, mask the fact that exchange rate and inflation are interdependent.*

Table 3

Selection of Studies on the Relationship between Crude Oil Prices and U.S. Dollar Exchange Rates

Study	Direction	Causality	Theory	Model	Period	Exchange rate data	Oil data	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 et al., 2005	Cointegration; long-term positive, but negative from 2002 on	Real oil → real USD Causality reversal as of 2002	China impacts via USD peg and energy-intensive growth	Four-country model (Krugman, 1980): U.S.A., China, OPEC (U.S. 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 and interest rates and 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	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 channel; Incomplete exchange rate pass-through	Partial market-sharing model, price leadership Saudi Arabia	1989–1999	REER USD (price adjusted Pmcdi + Pbdi)	WTI, Brent, OPEC and monthly spot prices	Hansen's GMM, perfect correlation
Amano and van Norden, 1998	Positively cointegrated	Oil → exchange rate	Real oil price reflects terms of trade shocks	Single equation error correction model	1972–1992	REER USD	Real WTI	Dynamic simulations

Source: OeNB.

Note: NEER: Nominal effective exchange rate; REER: Real effective exchange rate; WTI: West Texas Intermediate; VAR: Vector autoregression; VECM: Vector error correction-model; OLS: Ordinary least squares.

rate, gets increasing support (Cheng, 2008; Krichene, 2005; Yousefi and Wirjanto, 2005). Still, a considerable group of authors disagrees (Amano and van Norden, 1998; Bénassy-Quéré et al., 2005; Schimmel, 2008).

The impact of oil prices on exchange rates of currencies other than the U.S. dollar has 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 U.S. dollar. The apparent difference in terms of direction of causality between these results and most studies (including ours) on the U.S. dollar oil relation indicate that the U.S. 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 that commodities are affected by currencies rather than vice versa (Chen et al., 2008; Clements and Fry, 2006). A broader, less selective sample of commodity currencies, however, suggests the opposite conclusion (Cashin et al., 2004).

3 The U.S. 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 USD/EUR exchange rate contain information about future changes in oil prices.[18] For that purpose we compare the predictions of a simple autoregressive (AR) model on oil price changes with those of 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 VAR and VEC models, the specification can be interpreted as a monetary model of exchange rate determination augmented with an oil price variable (e.g. 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 in the U.S.A. and the euro area.

For both economies, the data for money supply refer to M1, production is proxied by the industrial production index and we use the 1-month money market rate as the relevant interest rate. The USD/EUR exchange rate prior to 1999 refers to the synthetic euro and the nominal oil price is U.S. dollar per barrel (West Texas Intermediate). All data are of monthly frequency, covering the period January 1983 to December 2007 and stem from Datastream with the exception of oil price data, whose source is the Energy Information Administration.[19]

The two competing models are 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

[18] *There are two reasons for the use of an out-of-sample approach. On the one hand, nesting all possible links in a single theoretical (structural) model, which would be needed to test the different channels properly, is a hopeless aim. This would imply developing a fully-fledged model for the whole world, whose assumptions could be just as readily criticized as the concentration on small partially reduced models such as the one we use here. This problem is also magnified by the fact that, empirically, some of the channels may be observationally equivalent. On the other hand, the focus on out-of-sample predictability may be seen as an extra value added of this study, in the sense that most of the literature concentrates on in-sample correlations which may or may not contain important information for prediction.*

[19] *We chose monthly data in order to limit white noise associated with higher frequencies and to better focus on fundamental drivers of data movements. We use nominal data not least because real data would enter the consumer price index which is endogenous to oil prices and exchange rates. Our series of interest is the front-month contract price of barrel of West Texas Intermediate (WTI) which is one of the three marker crudes (together with Brent and Dubai) whose prices are strongly linked to each other.*

$$\Delta v_t = \Theta_0 + \sum_{k=1}^{p} \Theta_k \Delta v_{t-k} + u_t \qquad (2)$$

where $v_t = (p_t\ e_t\ m_t\ y_t\ i_t)$, $p_t = ln(p_t)$, $e_t = ln(e_t)$, $m_t = ln(M_{t,US}/M_{t,EUR})$, $y_t = ln(Y_{t,US}/Y_{t,EUR})$, $i_t = (r_{t,US} - r_{t,EUR})$ 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 USD/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 $u_t = (u_{1t}\ u_{2t}\ u_{3t}\ u_{4t}\ u_{5t})$ is assumed to be an iid vector process with zero mean and a 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,

$$\Delta v_t = \Gamma_0 + \sum_{k=1}^{p} \Gamma_k \Delta v_{t-k} + \alpha\beta' v_{t-1} + u_t \qquad (3)$$

where β is the (column) cointegrating vector, which defines the long-run equilibrium among the variables of the system, given by $\beta' v_t$, and α is a (column) vector capturing the adjustment speed of each one of the components of 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 and 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 by 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

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

where p^h_t 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 model's ability of correctly forecasting the direction of change of the oil price.

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

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

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, $\bar{d}$ The DM test statistic is given by

$$S_1 = [\hat{V}(\bar{d})]^{-1/2}\bar{d} \qquad (6)$$

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

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

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 see Kunst (2003).

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; 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 six 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 VAR models.

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

Source: OeNB.

*Note: (*) 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. The best models for each forecasting horizon are in bold 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	0.410	**0.291**	**0.550**	0.365	0.480	100
12	0.370	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	0.250	0.547	0.197	**0.470***	**0.539**	76
36	0.569	0.151	0.565	0.164	**0.473****	**0.493**	73

Source: OeNB.

*Note: (*) 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. The best models for each forecasting horizon are in bold 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 alternative specifications. These results thus offer extra evidence concerning the fact that the USD/EUR exchange rate contains information about the future development of oil prices.

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 there is no statistical evidence of causality links between the two variables.[20]

4 Concluding Remarks

This paper provides evidence for the fact that exchange rates do matter in forecasting commodity prices. While, both from a theoretical perspective and from simple Granger-causality tests, the direction of causality is unclear, we show that exchange rate information significantly improves oil price forecasts. The negative correlation of these two variables is ascribed to five possible channels: a supply-side purchasing power channel, a demand-side local price channel, an asset market investment channel, a monetary policy regime channel and a currency market efficiency channel.

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

Future research should concentrate on modeling and testing the five channels of the U.S. dollar-oil nexus. Nonlinearity and asymmetries in the relation (Crespo Cuaresma et al., 2007), as well as the systematic exploitation of the cyclical component of oil price changes (see Rauscher, 1992, for a theoretical explanation and Crespo Cuaresma et al., 2007, for a recent empirical application) could be explored. The robustness of the forecasting models should be checked further 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 more light on the nature of the relationship between oil prices and exchange rates (Kilian and Park, 2007).

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

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