WORKING PAPER SERIES

The Relationship between Oil Prices and Exchange Rates: Theory and Evidence

Joscha Beckmann, Robert Czudaj, and Vipin Arora

June 2017

Table of Contents

Tables

Figures

Abstract

This paper reviews existing theoretical and empirical research on the relationship between oil prices and exchange rates. We start with theoretical transmission channels—which point to bi-directional causality. Empirical research—focused on either explaining or forecasting one variable with the other—is classified and shows that the evidence varies substantially depending on sample, country choice and empirical method. Yet there are some common patterns: (i) strong links between exchange rates and oil prices are frequently observed over the long-run; and (ii) either exchange rates or oil prices are a potentially useful predictor of the other variable in the short-run, but the effects are strongly time-varying. We also identify some important avenues for future research such as addressing time-varying predictability and optimal sample choice for forecasting.

About the Authors

Joscha Beckman: Ruhr University of Bochum, Chair for International Economics, D-44801 Bochum, e-mail: joscha.beckmann@rub.de, and Kiel Institute for the World Economy, Hindenburgufer 66, 24105 Kiel.

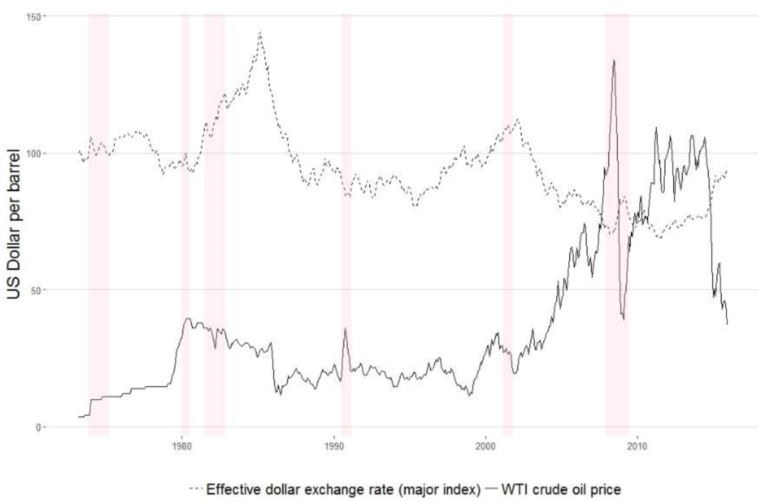
Robert Czudaj: Chemnitz University of Technology, Chair for Empirical Economics, D-09126 Chemnitz, e-mail: robert-lukas.czudaj@wirtschaft.tu-chemnitz.de, phone: (0049)-371-531-31323, fax: (0049)-371-531-831323.

Vipin Arora: US Energy Information Administration, 1000 Independence Ave, SW, Washington DC 20585, United States.

1. Introduction

Policymakers, academics and journalists have frequently discussed the link between oil prices and exchange rates in recent years—particularly the idea that an appreciation of the US dollar triggers a dip in oil prices. Empirical research is not so clear on the direction of causation, as there is evidence for bi-directional causality. Some studies find that an increase in the real oil price actually results in a real appreciation of the US dollar, while others show that a nominal appreciation of the US dollar triggers decreases in the oil price. Figure 1 illustrates the link between the nominal West Texas Intermediate (WTI) crude oil price and the US effective dollar exchange rate index relative to its main 7 trading partners.

Figure 1. Oil price vs. major US dollar index



Source: own illustration, data taken from Federal Reserve Economic Data.

This paper takes a closer look at the research dealing with the relationship between oil prices and exchange rates. After a brief review of theoretical transmission channels, we focus on a comprehensive and critical evaluation of empirical studies surrounding this research area.

We identify four major issues that need to be addressed in order to classify the oil price/exchange rate relationship. The first is to disentangle a backward ("in-sample") and a forward looking ("out-of-sample") empirical analysis. As will be discussed later, the frequent finding that exchange rates and oil prices move together over the long-run does not necessarily imply that one is useful when forecasting the other. The second challenge is to disentangle direct and indirect transmission channels. Direct channels are the influences either oil prices or exchange rates directly have on each other, whereas indirect channels are mainly due to other macroeconomic or financial factors. The third major task is to address the role of time-variation and nonlinearity. A final issue is related policy implications and open research questions.

The rest of this paper is organized as follows. Section 3 briefly summarizes various theoretical transmission channels which link oil prices and exchange rates. Based on those considerations, Sections 4 and 5 focus on in-sample validity of the identified transmission channels by reviewing empirical evidence over the short-run and long-run. The question of predictability between oil prices and exchange rate is considered in Section 6. The final two sections focus on policy recommendations and conclusions.

2. Classifications and definitions

The distinction between real and nominal measures is important when assessing the relationship between oil prices and exchange rates. The nominal spot exchange rate at a specific point in time $s_t$is expressed as domestic currency per US dollar, implying that an increase reflects a nominal appreciation of the US dollar,

$$s_t = \frac{domestic\ currency}{US\ Dollar}.$$

The real exchange rate (q_t) also includes price indices for both countries, and reflects the basket of domestic goods that can be purchased with one basket of US goods. This can be expressed as $q_t = s_t \frac{p_t}{p_{t^*}}$, where p_t and p_{t^*} denote domestic and foreign (i.e. US) price levels, usually approximated through consumer or producer prices. An increase is a real appreciation of the US dollar because the real purchasing power of US goods increases. This definition corresponds to the real exchange rate in external terms. Some studies consider the ratio between the prices of tradable and non-tradable goods; this is called the real exchange rate in internal terms, and a relative increase in the price of tradable goods corresponds to a real depreciation.[1]

The nominal oil price is usually measured in US dollars per barrel, as shown in Figure 1. The real oil price is calculated by adjusting the nominal oil price for any changes in the US price level (usually based on the US consumer price index (CPI)). Both nominal and real exchange rates can be expressed as a geometric or arithmetic trade weighted index between multiple countries, rather than just between two countries (so-called bi-lateral exchange rates). Such effective exchange rates reflect overall external competiveness for an economy Instead of analyzing current or spot price dynamics, another alternative is to focus on futures price dynamics, as these also reflect expectations. The futures price reflects the price at a given point t for delivery at t+h.

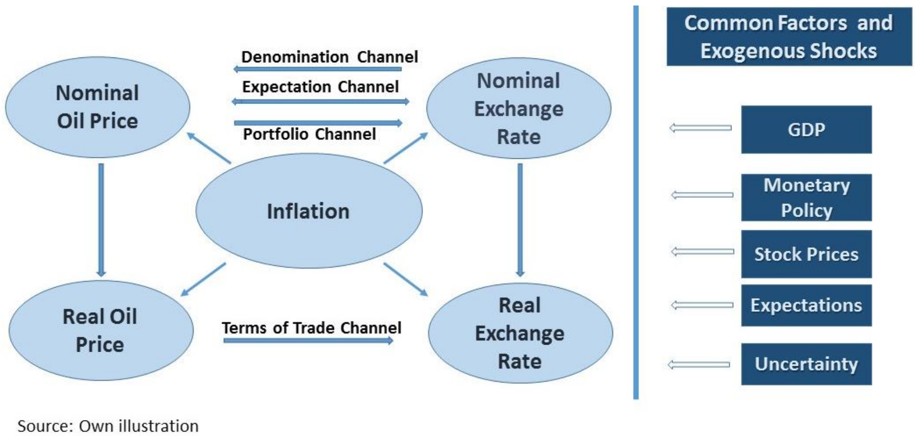
[1]The real exchange rate in external terms can be expressed as $q_t = s_t \frac{p_t}{p_{t^*}}$, where p_t and p_{t^*} denote domestic and foreign (i.e. US) price levels, usually approximated through consumer or producer prices.

3. Theoretical transmission mechanisms

Before we turn to the empirical evidence, it is important to identify theoretical links between oil prices and exchange rates. The various transmission channels are summarized in Figure 2.

The terms of trade channel mostly focuses on real oil prices and exchange rates, while the wealth and portfolio channels propose an effect from the nominal exchange rate to the nominal oil price. The expectations channel allows for nominal causalities in both directions.

Figure 2. Oil price and exchange rate causalities



Source: own illustration

3.1 The impact of oil prices on exchange rates

The literature considers three direct transmission channels of oil prices to exchange rates: the terms of trade channel, the wealth effect channel and the portfolio reallocation channel (Buetzer et al, 2016).

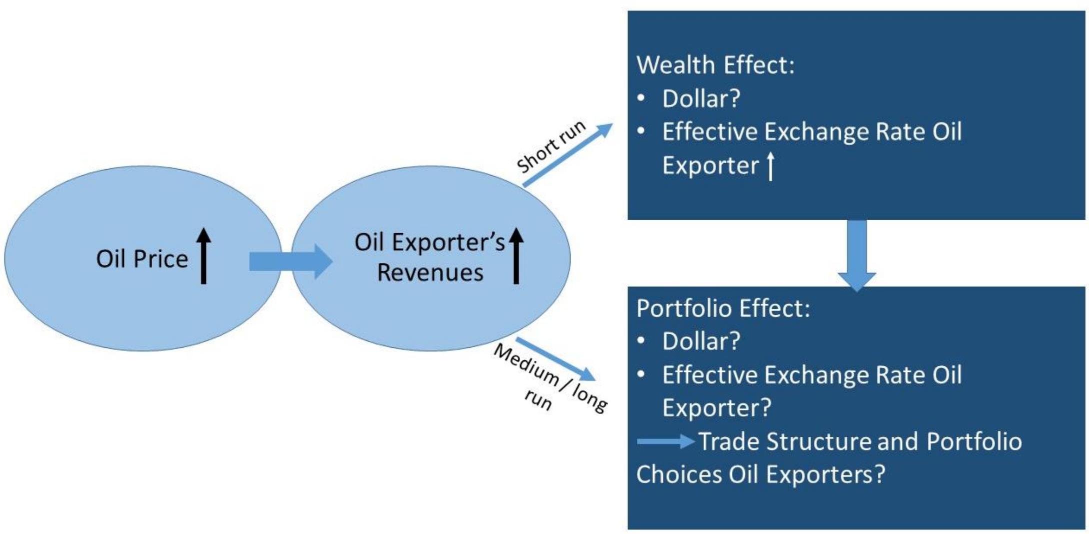
The terms of trade channel was introduced by Amano and van Norden (1998a, b). The underlying idea is to link the price of oil to the price level which affects the real exchange rate (Bénassy-Quéré et al., 2007). If the non-tradable sector of a country A is more energy intensive than the tradable one, the output price of this sector will increase relative to the output price of country B. This implies that the currency of country A experiences a real appreciation due to higher inflation (Chen and Chen, 2007; Buetzer et al., 2016).

Effects on the nominal exchange rate arise if the price of tradable goods is no longer assumed to be fixed. In this case, inflation and nominal exchange rate dynamics are related via purchasing power parity (PPP). If the price of oil increases, we expect currencies of countries with large oil dependence in the tradable sector to depreciate due to higher inflation. The response of the real exchange rate then depends on how the nominal exchange rate changes, but relative to the impact of any changes in the price of tradable (and non-tradable) goods described above. Overall, causality embedded in the terms of trade channel potentially holds over different horizons depending on the adjustment of prices.

The underlying idea of the portfolio and wealth channel, introduced by Krugman (1983) and Golub (1983), is based on a three country framework and has been reconsidered by Bodenstein et al. (2011). The basic idea is that oil-exporting countries experience a wealth transfer if the oil price rises (Bénassy-Quéré et al., 2007). The wealth channel reflects the resulting short-run effect, while the portfolio channel assesses medium- and long-run impacts. When oil prices rise, wealth is transferred to oil-exporting countries (in US dollar terms) and is reflected as an improvement in exports and the current account balance in domestic currency terms. For this reason, we expect currencies of oil-exporting countries to appreciate and currencies of oil-importers to depreciate in effective terms after a rise in oil prices (Beckmann and Czudaj, 2013b). There is also the possibility that the US dollar appreciates in the short-run because of the wealth effect—if oil-exporting countries reinvest their revenues in US dollar assets.

The short- and medium-run effects on the US dollar relative to currencies of oil-exporters will depend on two factors according to the portfolio effect. The first is the dependence of the United States on oil-imports relative to the share of US exports to oil-producing countries. The second is oil exporters' relative preferences for US dollar assets (Bénassy-Quéré et al., 2007; Coudert et al., 2008; Buetzer et al., 2016). Figure 3 summarizes the wealth and portfolio channels.

Figure 3. Wealth and portfolio channel



Source: own illustration

3.2 The impact of exchange rates on oil prices

The theoretical starting point for causality from exchange rates to oil prices is the fact that the oil price is denominated in US dollars. Abstracting from transaction costs, consider the following relationship between the logarithms of the oil price denominated in a local currency (o_t) and the US dollar (o_t^*) based on the law of one price

$$o_t^* = s_t - o_t.$$

Following this equation, an appreciation of the US dollar increases the price of oil measured in terms of the domestic currency, and this lowers demand for oil outside the US, resulting in a drop in the oil price, all else equal (Bloomberg and Harris, 1995; Akram, 2009).

Effects on the supply side are potentially relevant but less frequently discussed, mainly because they are subject to several other factors affecting price setting and production. Positive supply responses may stem from a rise in the oil price due to a US dollar appreciation if drilling activity and/or production capacity increases (Coudert et al., 2008). Oil-exporting companies or countries might also decide to adjust oil prices or supply as a response to exchange rate changes depending on their price strategy (Yousefi and Wirjanto, 2004).[2]

Effects on the supply side are potentially relevant but less frequently discussed, mainly because they are subject to several other factors affecting price setting and production. Positive supply responses may stem from a rise in the oil price due to a US dollar appreciation if drilling activity and/or production capacity increases (Coudert et al., 2008). Oil-exporting companies or countries might also decide to adjust oil prices or supply as a response to exchange rate changes depending on their price strategy (Yousefi and Wirjanto, 2004).[3] If market participants are aware of the underlying link outlined above, an appreciation of the US dollar immediately triggers expectations of a decrease in the price of oil, and oil futures might be considered a good hedge against an expected US dollar depreciation (Fratzscher at al., 2014). If both exchange rates and oil prices are viewed as asset prices, the fact that both are jointly determined in equilibrium complicates the identification of (one-sided) clear causality (Chen et al., 2008). [4]

3.3 Common factors driving oil prices and exchange rates

Having already explained the role of inflation, Figure 2 incorporates other common factors including GDP, interest rates, stock prices and uncertainty. A full analysis of all possible linkages and other potential factors is beyond the scope of this paper, but a few important channels are worth mentioning.

GDP and interest rates both affect exchange rates and oil prices and are also interrelated: Monetary policy reacts to GDP fluctuations[5] while interest rate changes affect GDP through total investment and total spending. An increase in GDP, all else equal, results in an increase in the oil price. Effects on exchange rates are less clear for both interest and exchange rates. A relative increase in domestic interest rates should for example depreciate the domestic currency according to uncovered interest rate parity, but the empirical evidence has demonstrated that an appreciation is frequently observed

---

[2] In the case of partial or full exchange rate pass-through, foreign oil-producers potentially increase the price of oil, or cut supply, if the US dollar depreciates—and vice versa (Fratzscher et al., 2014). Following a pricing to market strategy they may hold the oil price in US dollars fixed.

[3] In the case of partial or full exchange rate pass-through, foreign oil-producers potentially increase the price of oil, or cut supply, if the US dollar depreciates—and vice versa (Fratzscher et al., 2014). Following a pricing to market strategy they may hold the oil price in US dollars fixed.

[4] Whether or not the oil price should be considered a forward looking asset price is debated, but recent studies by Killian and Vega (2011) and Fratzscher et al. (2014) provide evidence for the view that oil prices react to changes in other financial assets.

[5] A central bank adjusts interest rates according to deviations of inflation and GDP from specific targets according to the Taylor rule principle.

instead, reflecting the notorious forward premium puzzle.[6] Another major influence on both the macroeconomic environment and exchange rate dynamics is the degree of uncertainty. A domestic appreciation of the exchange rate might result from uncertainty, if participants expect a currency to act as a safe haven (Beckmann and Czudaj, 2017).[7]

[6] It is also worth mentioning that the intensity of the link between oil prices and exchange rates is of potential relevance for monetary policymakers. A central bank which aims at price stability will react less to inflationary effects stemming from oil prices which are at least partially offset by a change in domestic currency value. Central banks which adopt exchange rate targeting will also take such linkages into account (Reboredo, 2012; Beckmann and Czudaj, 2013a).

[7] A possible explanation is that market participants consider news about a weakening of the US economy to have even worse effects for other countries (Fratzscher, 2009).

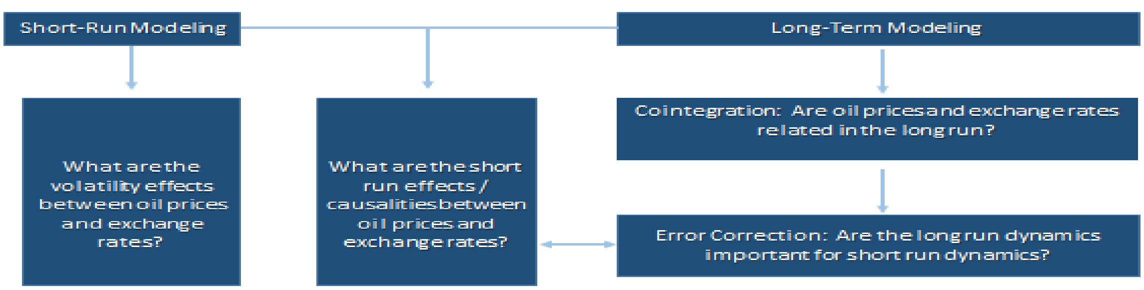
4. Long-run in-sample evidence between exchange rates and oil prices

4.1 General classification of empirical methods and data used

As mentioned in the introduction, in-sample estimates consider the historical relationship between the price of oil and exchange rates, while out-of-sample analyses use information up to a point t to make predictions about time t+h. The term "pseudo out-of-sample" corresponds to a situation where future realizations are used as predictors. A crucial question that arises when studying historical relationships is whether knowledge about the past is important when making predictions for the future. Empirical questions usually address two different issues: The causality between oil prices and exchange rates, and/or the intensity of the link between them.

Figure 4 provides a first distinction between long-run and short-run analysis. The underlying concept of cointegration relies on the idea of a stable long-run equilibrium with short-run deviations above and below it that are corrected over time. If exchange rates and oil prices share a long-run (cointegrating) relationship, they (potentially) still deviate from this relationship in the short-run. The long-run coefficient characterizes the intensity of the relationship between both variables. A related question is which variable reacts to deviations from the long-run equilibrium. The so-called error correction mechanism captures 1.) the speed with which deviations from a long-run equilibrium are corrected; and 2.) the variables responsible for such corrections.

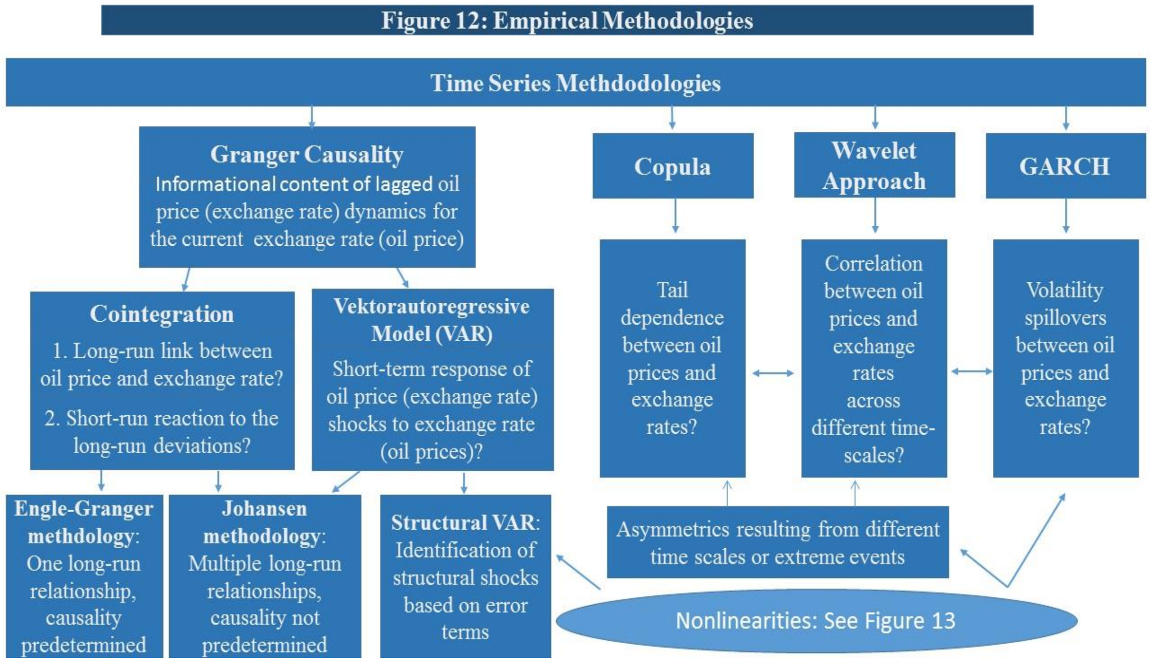
Figure 4. Long-run vs. short-run dynamics



Source: own illustration

The classification of empirical evidence shown in Figure 5 also reflects the distinction between short-run and long-run dynamics and provides a good guideline for the discussion of empirical results. The classified methods all correspond to country-specific time series dynamics since such frameworks are most frequently adopted. slower than countries such as India, where GDP is substantially underestimated because of price differences.

Figure 5. Empirical Methodologies



Source: own illustration

The simplest measure corresponds to Granger causality, which analyzes whether past oil prices or exchange rates help explain the current value of the other variable. In the context of vector autoregressive models (VAR) models, another frequently adopted technique is the consideration of impulse response functions. They measure the reaction of one variable to a shock of another variable. The general advantage of VAR models is that oil and exchange rate dynamics can be assessed without any assumptions related to causalities. Structural vector autoregressive models (VAR) models additionally include some theory guided restrictions when shocks are implemented. Such a proceeding allows for providing a distinction between supply and demand shocks in the context of oil prices, and allows for an important bridge between theory and empirics.

The idea of cointegration is also related to Granger causality. When conducting cointegration analysis, the long-run coefficient reflects the direction and intensity of the long-run relationship between the nominal oil price and exchange rates. The adjustment coefficients measure the speed of adjustment to long-run deviations for each variable. If, as an example, only the oil price (but not the exchange rate) adjusts to long-run equilibrium, the causality essentially runs from oil prices to exchange rates. Two different frameworks are considered in the context of cointegration: The Engle-Granger (1987) methodology adopts single equation estimates where one variable is assumed to be the dependent variable. The multivariate Johansen (1988) methodology essentially resembles a VAR model which incorporates long-run dynamics and allows for the simultaneous estimation of several long-run relationships, if detected.

Short-run dynamics often focus on contemporaneous correlations or spillovers rather than lead-lag relationships. Generalized autoregressive conditional heteroscedasticity (GARCH) models are the most common framework to assess short-run volatility spillovers. Recent studies also consider copula and wavelet approaches (Beckmann et al., 2016). Such frameworks can be extended in various directions based on assumptions related to the underlying kind of volatility. Copula frameworks assess and compare relationships in turbulent and normal times by allowing for tail dependency, i.e. dependency in the tails of both distributions. Wavelet approaches are adopted to compare dependencies between oil price and exchange rates over different frequencies. The different scales are denominated 2i, where i denotes the time frequency. The first frequency corresponds to changes between 21= 2 days, while the second frequency corresponds to changes between 22= 4 days, with the same logic adopted for higher frequencies. Essentially, both wavelet and copulas reflect specific forms of asymmetry or nonlinearity by accounting for different relationships across frequencies (wavelet) or between normal and turbulent times (copulas). Approaches which account for nonlinearities and different approaches for evaluating forecasts will be discussed after the next section.

4.2 Empirical Results

4.2.1 Main empirical results

The long-run relationship between the price of oil and exchange rates has been analyzed for several countries in a range of studies. These cover various spans of data and use both effective and bilateral exchange rates, as well as nominal and real oil prices.

The bottom line is that several studies have provided evidence for a long-run relationship between exchange rates and oil. One type of study has focused on the link between the real oil price and real US dollar exchange rates. Many authors have identified a long-run relationship between both, suggesting that a real effective appreciation of the US dollar coincides with an increase in the real oil price over the long-run (Amano and van Norden, 1998a; Coudert et al., 2008 and Bénassy-Quéré et al., 2007; Beckmann and Czudaj; 2013b). Similar findings have been obtained for bilateral real exchange rates.

Clostermann and Schnatz (2000) establish a long-term link between the real US dollar-euro exchange rate and the oil price, while Chaudhuri and Daniel (1998) assess real US dollar exchange rates for 16 OECD countries and detect a cointegrating relationship between most of them. Chen and Chen (2007) use a panel of G7 countries and find that real oil prices have significantly contributed to real exchange rate movements.

In line with the terms-of trade channel discussed in Section 2, most studies find that the price of oil affects the exchange rate, but not vice versa. However, it is important to emphasize that the existence of a long-term relationship does not necessarily imply strong linkages in the short-run. In the case of linear models, the adjustment to restore disequilibria in many cases is estimated to be higher than 5 years, calling into question any practical relevance. There are also several studies which fail to establish a cointegrating relationship between exchange rates and the price of oil.

4.2.2 Oil-importing countries, oil-exporting countries and sample choices

The terms of trade channel discussed in Section 2 has inspired several authors to focus on effective exchange rates of oil-importers and oil-exporters. The findings differ remarkably across studies and countries. The link between nominal exchange rates and price differentials (reflecting the validity of purchasing power parity (PPP), which constitutes a part of the terms of trade channel) is characterized by several nonlinearities. PPP is more relevant over the long-run and in the case of high inflation differentials (Taylor et al., 2001; Kilian and Taylor 2003; Sarno, 2005).

Habib and Kalamova (2007) do not find a long-run relationship between real effective exchange rates and the oil price for Norway and Saudi Arabia, but report evidence for a long-run real appreciation in Russia if the oil price rises. On the other hand, Al-Mulali (2010) provides evidence for a real effective appreciation in the case of an increase in the real oil price. Camarero and Tamarit (2002) find that real oil prices explain the real exchange rate for the Spanish peseta, while Huang and Guo (2007) show that real oil price shocks imply an appreciation of the real exchange rate for China based on a structural VAR.

On the other hand, the findings of two recent studies clearly show that there is no unique link between the real oil price and real effective exchange rates of oil-exporters and oil-importers. Buetzer et al.

(2016) identify various shocks to real oil prices in a structural VAR and find no systematic evidence that the exchange rates of oil exporters appreciate against those of oil importers (for a set of 43 countries). One explanation for the missing link is that countries with a higher oil surplus intervene in the foreign exchange rate market to prevent appreciation pressures.

Beckmann and Czudaj (2013b) analyze a group of 10 economies and find that the results differ not only between, but also within the group of oil-exporters and oil-importers. They find that changes in nominal oil prices trigger real exchange rate effects through the nominal exchange rate and price differentials. Nominal appreciation against the US dollar is mainly observed for oil-exporting countries, while nominal depreciation is detected for importing and exporting countries. They also find reverse causality, in the sense that nominal exchange rates influence nominal oil prices in some cases. The more general evidence on commodity producing countries also suggests a strong link between real exchange rate appreciations and an increase in commodity prices. Bodart et al. (2012) analyze 68 economies and find that such an effect is observed if the dominant commodity accounts for at least 20 percent of total exports. Overall, there is a clear evidence that sample selection affects empirical results, and offers an explanation for the huge dispersion of empirical findings across studies which analyze causalities between oil prices and exchange rates.

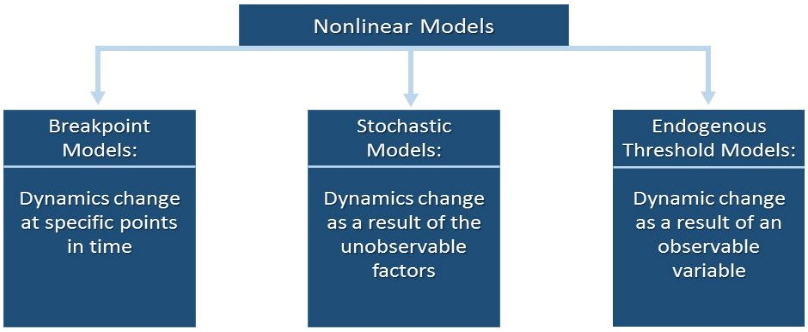
4.2.3 Time-varying relationships

The previous section has illustrated that the empirical findings differ over time, suggesting that instabilities are a key ingredient for understanding the oil price-exchange rate link.

Identifying and explaining structural changes represents a major economic and econometric task, and has inspired several lines of research on the relationship between oil prices and exchange rates. Figure 6 summarizes different kinds of nonlinearities. The first possibility is that the relationship between the price of oil and exchange rates changes at a specific point in time. Two different ideas for identifying regime changes can be distinguished. One possibility is to identify a variable which is responsible for such changes, for example a specific threshold of an observed variable.[8] Such models are easy to handle in terms of interpretation and are well-suited to capture the underlying dynamics if the data is primarily generated by market forces (Balke and Fomby, 1997). However, if exogenous factors such as policy interventions or abnormal global economic crises affect the data, a stochastic framework which does not require a transition variable, such as a Markov-switching approach is better suited.

[8] These effects can be formally derived in the context of international arbitrage costs (Taylor et al., 2001).

Figure 6. Characteristics of Nonlinearities



Source: own illustration

Several authors have adopted nonlinear frameworks when assessing the link between oil prices and exchange rates. Akram (2004) introduced nonlinear dynamics into the literature on oil prices and exchange rates. He identifies a nonlinear negative relationship between the value of the Norwegian krone and crude oil prices based on a threshold model where the change of the oil price determines the underlying dynamics. The intensity of the link depends on whether fluctuations are within or outside the normal range, and whether oil prices are falling or rising. Allowing for nonlinearities is also important when assessing a long-run relationship between oil prices and exchange rates. The finding by Zhang (2013), that detecting a long-run relationship between the real oil price and the real effective exchange depends on allowing for structural breaks, reflects the well-established fact that oil price and exchange rate dynamics are subject to structural breaks. Beckmann and Czudaj (2013b) rely on a Markov-switching vector error correction model (MS-VECM) and find that adjustment dynamics often differ significantly between regimes. For most countries oil prices only adjust to long-run deviations in one of the two regimes, while adjustment speed is often higher in one of the two regimes. Basher et al. (2016) also apply a Markov-switching approach and identify exchange rate appreciation pressures in oil-exporting economies after oil demand shocks, but find limited evidence that oil supply shocks display a similar effect on exchange rates. As discussed above, wavelet and copula approaches also capture nonlinear patterns in the short-run.

5. Short-run in-sample evidence between exchange rates and oil prices

5.1 Main empirical results

Many studies dealing with short-run dynamics between exchange rates and the price of oil point to a causal chain from the US dollar exchange rate to the nominal oil price. Short-term studies analyze both daily and monthly frequencies, and we begin by summarizing studies dealing with monthly data. The first empirical study which related empirical oil price-exchange rate dynamics was provided by Trehan (1986). He argues that the effect of oil price shocks on the US economy is likely to be exaggerated because the oil price is denominated in US dollars and should not be considered as exogenous. Since then, several authors have directly analyzed the effects of exchange rate changes on the price of oil. Among other, Cheng (2008) finds an increase in the real (nominal) oil price as a response to a real (nominal) effective US dollar appreciation.

Some studies have also focused on the response of oil demand and supply to exchange rate shocks. Yousefi and Wirjanto (2004) analyze five OPEC countries and provide evidence that crude oil export prices respond positively to US dollar depreciations. A recent study by De Schryder and Peersman (2016) offers an interesting perspective on the link between exchange rates and the oil demand of oil importing countries. They identify a significant decline in the oil demand of 65 oil-importing countries as a result of an appreciation of the US dollar. Such demand effects are even stronger than exchange rate effects on the global price of crude oil. This pattern can potentially be explained by stronger pass-through of changes in the US dollar exchange rate to domestic end-user oil product prices.

There is also plenty of evidence based on structural VARs which focuses on causality in the other direction, and distinguish between oil demand and supply shocks when analyzing exchange rate responses. Basher et al. (2012) focus on emerging markets and provide evidence for short-run effects of oil price shocks on exchange rates. The results of Basher et al. (2016), based on a similar methodology, show that oil demand shocks have stronger effects on oil-exporter exchange rates as compared to oil supply shocks.

A comprehensive study by Fratzscher et al. (2014) identifies bi-directional causality between the US dollar and oil prices since the early 2000s. They focus on daily data between January 2001 and 2012 and conclude that oil has become a global commodity whose price is driven not only by US-specific factors, but also financial ones (in particular asset prices). For the sample period they also find that a 10% increase in the price of oil leads to a depreciation of the US dollar effective exchange rate by 0.28%, while a 1% US dollar depreciation causes oil prices to rise by 0.73%.

Studies dealing with volatility spillovers also find evidence for bi-directional causality over recent years. Several authors find evidence for causalities between the price of oil and different exchange rates. Ghosh (2011) focuses on the periods from 2007 until 2008 and finds that oil price increases depreciate the Indian rupee relative to the US dollar at a daily frequency. As discussed previously, possible explanations for the sample and currency-dependent findings include common factors and asymmetries.[9] Cifarelli, G., and Paladino (2010) partly address the role of stock prices as a common factor. He focuses on spillovers between oil prices, stock prices and US dollar exchange rates and finds that oil price shifts are negatively related to exchange rate changes. Jiang (2016) analyzes 13 currencies, 4 of them at a daily frequency, and finds asymmetric correlations between oil prices and exchange rates—with more consistent correlations in case of small fluctuations.

Several studies also find short-run effects of oil price changes on exchange rates by comparing different frequencies. Benhmad (2012) conducts a wavelet analysis for real US dollar exchange rates and finds causality from oil prices to exchange rates over higher frequencies. The results over larger horizons point to bivariate causalities, but have potentially less explanatory power due to a smaller number of observations. Bouoiyour et al. (2015) also finds causality from oil price changes to the real exchange rate of Russia

5.2 Time-varying relationships and evidence across different sample periods

There is plenty of evidence that the main drivers of oil price changes are subject to structural breaks and can vary over time. Fan and Xu (2011) find that the price of oil has become more closely related to macroeconomic fundamentals and financial markets over time. Their findings are based on a wavelet approach that also suggests the link between US dollar exchange rates and oil has intensified over time.

Many recent studies also find that the relationship between exchange rates and the price of oil has become more time-varying, in particular after 2009. An early study by Zhang (2008), which analyzes the period between 2000 and 2005, finds a long-term equilibrium relationship between oil prices and euro/US dollar exchange rates, but reports little evidence for risk or volatility spillovers. This is in contrast to findings by Reboredo (2012) and Beckmann et al. (2016) which include the period after September 2008. Both studies rely on copula models and find that the intensity of the relationship between oil prices and US dollar exchange rates increased immediately after the onset of the financial crisis, and is stronger during extreme events. Reboredo (2012) additionally finds that the linkages turn out to be stronger for oil exporters. The findings by Beckmann et al. (2016) also point to relevance for the wealth channel. They find that appreciations (depreciations) are positively correlated with an increase in oil prices for oil exporters (oil importers).

Reboredo and Rivera-Castro (2013) adopt a wavelet approach and also identify a much stronger relationship after the onset of the financial crisis. The results of Turhan et al. (2014), based on dynamic conditional correlations, also finds that the correlation has increased and become strongly negative over

[9] The study by Bal and Rath (2015) provides an example for the instability of empirical results. They identify statistically significant bi-directional nonlinear Granger causality between the real effective exchange rates of India and China and the real oil price. However, De Vita and Trachanas (2016) point to misspecifications in their study and come to different conclusions based on the same dataset.

recent years. Jawadi et al. (2016) focus solely on the euro/US dollar exchange rate from 2014 and 2016, and find significant volatility spillovers from the exchange rate to oil prices using intraday data.

5.3 Reconciling evidence and theory

The various short-run linkages identified in empirical studies confirm the importance of both the denomination and the portfolio channel. There is also a strong consensus that the link between higher oil prices and US dollar depreciations has become stronger over recent years. While studies point to bi-directional causality, exchange rate changes are more important for oil prices changes as compared to the long-run. In the spirit of the denomination channel, these long-run studies often focus on effective exchange rates, whereas short-run dynamics are mostly based on bilateral US dollar exchange rates.

Results also show difficulty in explaining empirical short-run patterns from a theoretical perspective. At least the standard theoretical considerations don’t offer any direct explanation for dynamics identified by wavelet and copula frameworks, for example, intensifying dynamics between oil prices and exchange rates over time. Such changes are driven by factors which are exogenous in the different models.

Another important question that has not been fully analyzed in detail is the distinction between supply and demand side effects. Such a distinction could contribute to a deeper understanding of transmission channels between oil prices and exchange rates. The price setting behavior of oil suppliers and the implications of exchange pass-through would also add to an understanding of potential exchange rate effects on oil price dynamics.

Many studies that have established a time-varying relationship between oil prices and exchange rates over time rely on copula or wavelet approaches. While both frameworks are quite useful and well-suited to trace back such changes, they are rather descriptive and unable to establish causalities and/or consider common factors. The underlying question of why the link between the price of oil and exchange rates has become more time-varying has yet to be analyzed from either a theoretical or an empirical perspective. Obvious candidates include the changing stance of monetary policy and the financialization of commodity markets.

Another open issue is the role of policy announcements for oil price-exchange rate dynamics over recent years. There is plenty of evidence that exchange rates react to monetary policy announcements, in particular over the short-run. On the other hand, Kilian and Vega (2011) do not find evidence that energy prices (including oil prices) respond instantaneously to macroeconomic news.

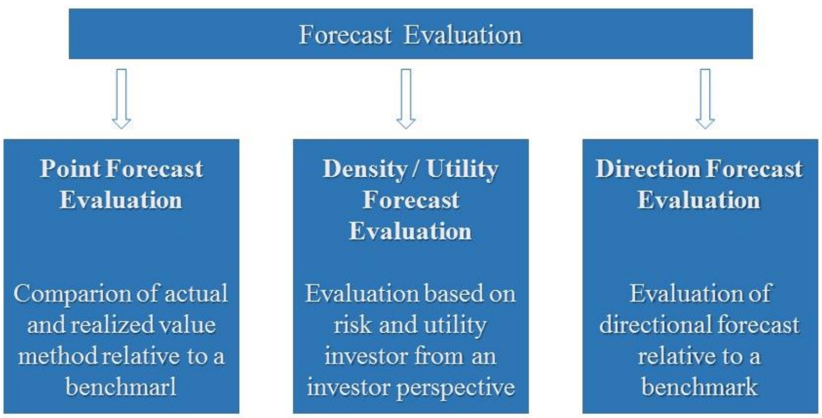
6. Out-of-sample evidence between exchange rates and oil prices

6.1 Classification of empirical methods

The evidence considered so far focuses on in-sample evidence and is not necessarily related to out-of-sample predictability. The literature on forecasting oil prices based on exchange rates (or vice versa) starts around 1973, after the breakdown of Bretton Woods. Prior to that point, nominal exchange rates were fixed relative to the US dollar. As mentioned in Section 4.1, the literature on forecasting considers statistical and economic criteria for evaluating forecasts.

Figure 6 summarizes the different possibilities for assessing forecasts.

Figure 7. Forecast evaluation



Source: own illustration

Statistical criteria usually compare the point prediction of a specific model to a simple benchmark. In many cases the random walk without drift is considered to be the toughest benchmark. In such a framework, the predicted change is zero, i.e. today's value is considered to be the best predictor. There are two alternative forecast evaluation methods which have attracted less attention in the literature on oil prices and exchange rates. One is to focus on directional adequacy instead of analyzing point forecast adequacy. Another perspective is based on the economic value of forecasts, and considers utility measures based on dynamic asset allocation strategies.

6.2 Main empirical results

6.2.1 Predictive power of oil prices for exchange rates

The seminal work of Meese and Rogoff (1983)—showing that exchange rate models based on economic fundamentals are unable to outperform a simple random walk forecast—still constitutes a benchmark result in the international finance literature. The resulting exchange rate disconnect puzzle remains one of the most important topics in international economics (Sarno, 2005). In general, the forecasting performance of fundamental exchange rate models is highly sensitive to the selection of different currencies, sample periods and forecast horizons (Rossi, 2013). Similar to the in-sample evidence, country- and time-specific estimates should therefore be interpreted with caution.

Some papers have found evidence for improved exchange rate forecasts when including the price of oil. Lizardo and Mollick (2010) imbed the real oil price into a simple form of the monetary model of exchange rate determination and show that it improves exchange rate predictions for several bilateral currencies. However, the overall evidence suggests that this is not a systematic finding, nor is it robust to different time periods.

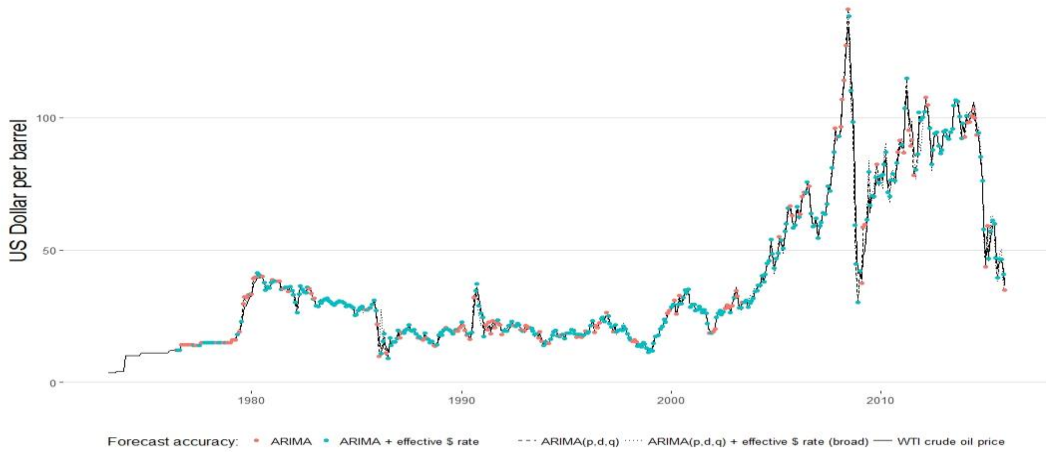
While one string of the literature has focused on oil-exporting currencies, other authors have turned their attention to commodity exporters such as Canada, Chile, New Zealand and Australia. Ferraro et al. (2015) argue that commodity prices predict commodity exporters' exchange rates at a daily frequency, and this is not evident at quarterly or monthly frequencies. Kohlscheen et al. (2016) find that commodity price models dominate random walk forecasts in the case of exchange rates. However, their findings are obtained based on a “pseudo-out-of-sample” exercise where future values of commodity prices are utilized. They point out that the evidence of out-of-sample predictability using only lagged predictors is clearly weaker, as a result of the fact that commodity prices are hard to predict. A reasonable conclusion is that the strong “pseudo-out-of-sample” findings are mostly driven by the correlation between exchange rates and commodity prices.

Kohlscheen et al. (2016) also provide useful insights on the relationship between country specific commodity price measures and oil prices. Indices for Colombia and Mexico, for instance, are highly correlated with the price of oil (0.971), while commodity baskets of other countries such as Chile display a much lower correlation with the oil price. This suggests that the literature on commodity prices should be considered for a better understanding of exchange rate-oil price dynamics.

6.2.2 Predictive power of exchange rates for oil prices

Before we turn to the existing literature, we analyze the potential of exchange rates for forecasting the price of oil out-of-sample by comparing two rolling window forecast models The first is a simple benchmark model and relies solely on information from the recent past (i.e. 40 observations) of the WTI crude oil price, while the second model also includes recent data on a US dollar exchange rate measure (the US effective dollar exchange rate broad index). We use both models to forecast the price of oil for four different horizons: one-month-ahead (h=1) and twelve-months-ahead (h=12). Figure 8 shows the corresponding results for h=1 and h=12 and reports the observed WTI crude oil price and the rolling window forecasts based on both models. The red dots reflect cases where the benchmark model is superior while the turquois dots represent the exchange rate model. The exchange rate model is better than the benchmark model over 50% of the time.

Figure 8. Oil price forecast with broad effective US dollar rate (h=1)



Source: own illustration, data taken from Federal Reserve Economic Data.

Table 1 summarizes results over the full sample for different forecasting horizons for the WTI oil price. [10]

Table 1. Share of forecasting superiority of exchange rate models against univariate models

	h=1	h=3	h=6	h=12
Broad index	0.7004219	0.559322	0.5479744	0.5723542
Major index	0.6561181	0.5635593	0.5714286	0.5226782

The results look encouraging at first sight, and confirm the general result that exchange rates are more useful for forecasting oil prices over the short-run. The percentage of periods where effective exchange rate dynamics add information, as opposed to relying solely on past oil prices, does not exceed 60% over 3, 6 and 12 months—while results are more favorable over the short-run. These patterns are confirmed for common exchange rate expectation dynamics and the Australian dollar, where the percentage is close to 75% for a shorter sample starting in 1995.

It is important to highlight that even these findings do not necessarily imply that exchange rate dynamics are useful for oil price predictions for a number of reasons. In terms of absolute differences, the exchange rate model does not outperform the simpler model by a large amount, while the simpler model in many cases outperforms the exchange rate model substantially. An example is the case where the simple model correctly proposes a constant oil price while the exchange rate model predicts changes which do not materialize.

[10] We have also performed the same exercise using either the Australian dollar exchange rate (as a commodity currency), a common factor across exchange rate expectations over the next month and the effective exchange rate of the US dollar against major currencies.

Taking these findings into account, it is not surprising that there is little systematic evidence that exchange rates are directly useful for oil price predictions. Baumeister et al. (2015) show within a mixed frequency approach that high-frequency financial data are hardly helpful in forecasting the monthly real price of oil. The survey by Alquist et al. (2011) provides a comprehensive overview on predictability of nominal or real oil prices based on macroeconomic aggregates. They conclude that neither short-term interest rates nor trade-weighted exchange rates have significant predictive power for the nominal price of oil in terms of point forecasts. However, they also argue that specific bilateral exchange rates might still be useful. They find that the Australian exchange rate has significant predictive power for the sign of the change in nominal oil prices over specific horizons.

Alquist et al. (2011) draw an important link to the study of Chen et al. (2010), which shows that exchange rates of commodity exporters ("commodity currencies") are helpful in forecasting country specific or aggregate commodity prices.[11] Their findings hold for Australia, Canada, Chile, New Zealand and South Africa where oil is not the primary exported commodity. Alquist et al. (2011) point to the strong link between other commodities and the price of oil, and argue that the predictive power of a commodity exporter's US dollar exchange rate might turn out be useful for oil price predictions via commodity prices. A related study by Groen and Pesenti (2011) analyzes a broad range of commodity prices and finds that exchange rates might be useful, but are not systematically more accurate predictors than simple benchmarks. Drachal (2016) addresses time variation in predictability by adopting a Dynamic Model Averaging framework for predicting the spot price of oil. He finds exchange rates to be important predictors between 1995 and 2000 and after 2005, while their relative importance diminishes between 2000 and 2005.

From an econometric perspective, the considerations so far have illustrated the issue of parameter and model uncertainty. On the one hand, all possible combinations of K potential explanatory variables for forecasting oil price or exchange rates result in 2^K different model specifications. In addition, coefficients of each model are subject to structural changes. A more common approach is to use Bayesian model averaging (BMA), which updates model weights and coefficient changes within a recursive learning scheme. These techniques are becoming more popular, and are increasingly used in the context of oil price and exchange rate predictions. Wright (2008), Della Corte et al. (2009) and Beckmann and Schüssler (2016) all adopt model averaging techniques in the context of exchange rate forecasting. When focusing on adequate oil price forecasts, Baumeister et al. (2014) and Baumeister and Kilian (2015) provide real-time out-of-sample evidence that the combination of forecasting models with equal weights dominates the approach of selecting one model and using it for all forecast horizons.

[11] Chen et al. (2014) find these results to be robust after the onset of the financial crisis.

8. Conclusion

This paper has addressed and summarized existing research on the link between oil prices and exchange rates. We have started by identifying different transmission channels which provide simple theoretical underpinnings of the relationship between exchange rates and the price of oil.

The empirical evidence is strongly time-varying and suggests that past relationships do not necessarily hold in the future, and the link between in-sample and out-of-sample is often rather weak. A model which successfully explains past oil price changes based on exchange rates is not necessarily useful for forecasting the price of oil in the next period. This complicates the task of selecting an adequate forecasting model and constitutes an important research question.

There is strong evidence that oil prices and exchange rates are related over the long-run. There is also a fair amount of evidence for various short-run linkages and spillovers between both markets at daily and monthly frequencies. The inverse causality from US dollar depreciations to increases in the price of oil often materializes at a daily frequency or over a few months.

A fair conclusion is that exchange rate movements are not a silver bullet for understanding or forecasting the price of oil—and vice versa—and neither is a substitute for supply or demand factors. However, each contains potentially useful information for forecasting the other and should be taken into account, particularly over the short-run. The oil price-exchange rate relationship is evolving over time and has recently become more volatile. The change in monetary policy and the financialization of commodity markets offer potential explanations for the intensified relationship. It remains to be seen whether the intensity of the link is affected by the proposed exit of unconventional monetary policy. From a policy perspective, an important question besides assessing flexible exchange rates is whether oil-exporting or oil-importing countries should be in favor of fixed or flexible exchange rate arrangements.[12]

Finally, we have identified a number of important open questions. Addressing time-varying predictability and sample choices is quite important since both exchange rates and oil prices are hard to predict. Several techniques to tackle the time-varying importance of one for forecasting the other have been discussed briefly. Relying on a data rich environment in a flexible econometric framework potentially addresses these issues but the rich toolset makes it difficult to identify one single framework. The idea of averaging across models and discounting past information in a Bayesian framework is very appealing and should be considered against various benchmarks. Factor models offer an alternative possibility for

[12] Commodity exporters are usually strongly affected by fluctuations in global markets. Dutch Disease corresponds to a situation where increasing prices of key exported goods lead to an appreciation of the domestic currency, and the stronger currency harms international competitiveness, negatively affecting other export sectors (Bodart et al., 2012). Fixed exchange rate arrangements are sometimes seen as beneficial in this regard since they prevent such depreciations and stabilize export revenues. However, the recent episode of falling oil prices has revitalized this discussion because fixed exchange rates also do not allow for domestic depreciations in the reverse scenario.

dealing with rich datasets. A first important avenue for future research is an extension of the study by Alquist et al. (2011). Considering that their sample ends in 2009, the argument that commodity exporter's exchange rates might be useful for oil price predictions deserves further attention over more recent periods.

Disentangling oil supply and demand factors is also quite important since most studies analyze the relationship between the oil price and exchange rate without separating oil demand and supply factors. Such a distinction is of great importance for a theoretical underpinning of the transmission channels from exchange rates to oil prices. The understanding of the exchange-rate pass-through of oil exporters potentially explains the time-varying ties between exchange rates and oil prices. Related to the issue of supply and demand, it also seems quite important to address the role of common factors, such as monetary policy drivers. At a minimum one should include these factors in an empirical investigation, while the optimal solution is an evaluation of potential indirect transmission channels. Policy announcements have already been identified as a potential driver of exchange rate volatility (Conrad and Lamla, 2010) and exchange rate expectations (Beckmann and Czudaj, 2016), while there has been much less written about their effect on oil prices. Finally, a critical evaluation of the economic value of predictions in a multivariate setup, for example in the spirit of Della Corte, Sarno and Tsiakas (2009), offers an interesting research avenue. Such an exercise potentially sheds some light on the question of whether exchange rates are a useful predictor for oil prices.

References

Al-Mulali, U. (2010). The Impact of Oil Prices on the Exchange Rate and Economic Growth in Norway. *MRPA Paper No. 26257*, University Library of Munich, Germany.

Alquist, R., Kilian, L., and Vigfusson, Robert J. (2011). Forecasting the Price of Oil. *International Finance Discussion Paper No. 1022*, Board of Governors of the Federal Reserve System.

Amano, R. A., and Van Norden, S. (1998a). Oil prices and the rise and fall of the US real exchange rate. *Journal of International Money and Finance*, 17(2), 299-316.

Amano, R. A., and Van Norden, S. (1998b). Exchange rates and oil prices. *Review of International Economics*, 6(4), 683-694.

Akram**,** Q. F. **(**2004**).** Oil prices and exchange rates: Norwegian evidence**.** Econometrics Journal**,** 7**,** 476**–**504.

Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. Energy Economics, 31(6), 838-851.

Bacchetta, P., and Van Wincoop, E. (2004). A scapegoat model of exchange-rate fluctuations. *American Economic Review*, 94(2), 114-118.

Bal, D. P., and Rath, B. N. (2015). Nonlinear causality between crude oil price and exchange rate: a comparative study of China and India. *Energy Economics*, 51, 149–156.

Balke, N. S., and Fomby, T. B. (1997). Threshold Cointegration. *International Economic Review*, 38(3), 627-645.

Basher, S. A., Haug, A. A., and Sadorsky, P. (2016). The impact of oil shocks on exchange rates: A Markov-switching approach. *Energy Economics*, 54, 11-23.

Baumeister, C., Guérin, P., and Kilian, L. (2015). Do high-frequency financial data help forecast oil prices? The MIDAS Touch at Work. *International Journal of Forecasting*, 31(2), 238-252.

Baumeister, C., Kilian, L., and Lee, T. K. (2014). Are there gains from pooling real-time oil price forecasts? *Energy Economics*, 46, 33-43.

Baumeister, C., and Kilian, L. (2015). Forecasting the real price of oil in a changing world: A forecast combination approach. *Journal of Business & Economic Statistics*, 33(3), 338-351.

Beckmann, J., and Czudaj, R. (2013a). Oil prices and effective dollar exchange rates. *International Review of Economics & Finance*, 27(1), 621-636.

Beckmann, J., and Czudaj, R. (2013b). Is there a homogeneous causality pattern between oil prices and currencies of oil importers and exporters? *Energy Economics*, 40(1), 665-678.

Beckmann, J., Berger, T., and Czudaj, R. (2016). Oil price and FX-rates dependency. *Quantitative Finance*, 16(3), 477-488.

Beckmann, J., and Czudaj, R. (2017). Exchange rate expectations and economic policy uncertainty. *European Journal of Political Economy*, forthcoming.

Beckmann, J., and Schüssler, R. (2016). Forecasting exchange rates under parameter and model uncertainty. *Journal of International Money and Finance*, 60, 267-288.

Benhmad, F. (2012). Modeling nonlinear Granger causality between the oil price and U.S. dollar: A wavelet based approach. *Economic Modelling*, 29(4), 1505-1514.

Bénassy-Quéré, A., Mignon, V., and Penot, A. (2007). China and the relationship between the oil price and the dollar. *Energy Policy*, 35(11), 5795-5805.

Bloomberg, S. B., and Harris, E. S. (1995). The commodity–consumer price connection: Fact or fable? Federal Reserve Board of New York. *Economic Policy Review*, 21-38.

Bodart, V., Candelon, B., and Carpantier, J.-F. (2012). Real exchanges rates in commodity producing countries: A reappraisal. *Journal of International Money and Finance*, 31(6), 1482-1502.

Bodenstein, M., Erceg, C. J., and Guerrieri, L. (2011). Oil Shocks and external adjustment. *Journal of International Economics*, 83(2), 168-184.

Bouoiyour, J., Selmi, R., Tiwari, A. K., and Shahbaz, M. (2015). The nexus between oil price and Russia's real exchange rate: Better paths via unconditional vs conditional analysis. *Energy Economics*, 51, 54–66.

Buetzer, S., Habib, M. M., and Stracca, L. (2016). Global exchange rate configurations: Do oil shocks matter? *IMF Economic Review*, 64(3), 443-470.

Camarero, M., and Tamarit, C. (2002). A panel cointegration approach to the estimation of the peseta real exchange rate. *Journal of Macroeconomics*, 24(3), 371-393.

Chaudhuri, K., and Daniel, B. C. (1998). Long-run equilibrium real exchange rates and oil prices. *Economics Letters*, 58(2), 231-238.

Chen, S.-S., and Chen, H.-C. (2007). Oil prices and real exchange rates. *Energy Economics*, 29(3), 390-404.

Chen, Y.-C., Rogoff, K. S., and Rossi, B. (2010). Can Exchange Rates Forecast Commodity Prices*? Quarterly Journal of Economics*, 125(3), 1145-1194.

Cheng, K. C. (2008). Dollar depreciation and commodity prices. *IMF, World Economic Outlook*, April, 48–50.

Cifarelli, G., and Paladino, G. (2010). Oil price dynamics and speculation: A multivariate financial approach. *Energy Economics*, 32(2), 363-372.

Clostermann, J., and Schnatz, B. (2000). The determinants of the euro-dollar exchange rate. Synthetic fundamentals and a non-existing currency. *Konjunkturpolitik, Applied Economics Quarterly*, 46, 207-230.

Conrad, C., and Lamla, M. J. (2010). The high-frequency response of the EUR-USD exchange rate to ECB Communication. *Journal of Money, Credit and Banking*, 42, 1391–1417.

Coudert, V., Mignon, V., and Penot, A. (2008). Oil price and the dollar. *Energy Studies Review*, 15(2), 45-58.

De Vita, G., and Trachanas, E. (2016). Nonlinear causality between crude oil price and exchange rate: A comparative study of China and India' — A failed replication (negative Type 1 and Type 2). *Energy Economics*, 56(C), 150-160.

Della Corte, P., Sarno, L., and Tsiakas, I. (2009). An economic evaluation of empirical exchange rate models. *Review of Financial Studies*, 22(9), 3491-3530.

De Schryder, S., and Peersman, G. (2015). The U.S. dollar exchange rate and the demand for oil. *Energy Journal*, 36(3), 263-285.

Drachal, K. (2016). Forecasting spot oil price in a dynamic model averaging framework -

Have the determinants changed over time? *Energy Economics,* 60, 35-46.

Engel, C., and West, K. D. (2005). Exchange rates and fundamentals. *Journal of Political Economy*, 113, 485-517.

Engle, R. F., and Granger, C. W. J. (1987). Cointegration and error correction: Representation, estimation and testing. *Econometrica*, 55, 251-276.

Fan, Y., and Xu, J.-H. (2011). What has driven prices since 2000? A structural change perspective. *Energy Economics*, 33(6), 1082-1094.

Ferraro, D., Rogoff, K., and Rossi, B. (2015). Can oil prices forecast exchange rates? An empirical analysis of the relationship between commodity prices and exchange rates*. Journal of International Money and Finance*, 54, 116-141.

Fratzscher, M. (2009). What explains global exchange rate movements during the financial crisis? *Journal of International Money and Finance*, 28, 1390-1407.

Fratzscher, M., Schneider, D., and Van Robays, I. (2014). Oil prices, exchange rates and asset prices. *Working Paper Series No 1689*, European Central Bank.

Golub, S. (1983). Oil prices and exchange rates. *The Economic Journal*, 93(371), 576-593.

Ghosh, S. (2011). Examining crude oil price – Exchange rate nexus for India during the period of extreme oil price volatility. *Applied Energy*, 88(5), 1886–1889.

Groen, J. J., and Pesenti, P. A. (2011). Commodity prices, commodity currencies, and global economic developments. *Commodity Prices and Markets, East Asia Seminar on* Economics, 20, 15-42, University of Chicago Press.

Habib M. M., and Kalamova M. (2007). Are there oil currencies? The real exchange rate of oil exporting countries. *European Central Bank Working Paper Series No 839*.

Huang, Y., and Guo, F. (2007). The role of oil price shocks on China's real exchange rate. *China Economic Review*, 18(4), 403-416.

Jawadi, F., Louhichi, W., Ameur, H. B., and Cheffou, A. I. (2016). On oil-US exchange rate volatility relationships: An intraday analysis. *Economic Modelling*, 59(C), 329-334.

Jiang, J., and Gu, R. (2016). Asymmetrical long-run dependence between oil price and US dollar exchange rate—Based on structural oil shocks. *Physica A: Statistical Mechanics and its Applications*, 456(C), 75-89.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, 12, 231-254.

Kilian, L., and Taylor, M. (2003). Why is it so difficult to beat the random walk forecast of exchange rates? *Journal of International Economics*, 60(1), 85-107.

Kilian, L., and Vega, C. (2011). Do energy prices respond to U.S. macroeconomic news? A test of the hypothesis of predetermined energy prices. *Review of Economics and Statistics*, 93(2), 660-671.

Kohlscheen, E., Avalos, F. H., and Schrimpf, A. (2016). When the walk is not random: commodity prices and exchange rates*. BIS Working Papers No 551.*

Krugman, P. (1983). Oil and the dollar. In B. Jagdeeps, & P. Bulfordh (Eds.), Economic interdependence and flexible exchange rates. Cambridge, MA: MIT Press.

Lizardo, R. A., and Mollick, A. V. (2010). Oil price fluctuations and U.S. dollar exchange rates. *Energy Economics*, 32(2), 399-408.

Meese, R. A., and Rogoff, K. (1983). Empirical exchange rate models of the seventies: Do they fit out of sample? *Journal of International Economics*, 14(1-2), 3-24.

Reboredo, J. C. (2012). Modelling oil price and exchange rate co-movements. *Journal of Policy Modeling*, 34(3), 419-440.

Reboredo, J., and Rivera-Castro, M. A. (2013). A wavelet decomposition approach to crude oil price and exchange rate dependence, *Economic Modelling*, 32 (C), 42-57.

Rossi, B. (2012). The changing relationship between commodity prices and equity prices in commodity exporting. *Economics Working Papers 1405*, Department of Economics and Business, ICREA-Universitat Pompeu Fabra.

Rossi, B. (2013). Exchange rate predictability. *Journal of Economic Literature, 51*(4), 1063-1119.

Sarno, L. (2005). Towards a solution to the puzzles in exchange rate economics: Where Do We Stand? *Working Papers 05-11*, Warwick Business School, Finance Group.

Taylor, M. P., Peel, D. A., and Sarno, L. (2001). Nonlinear mean-reversion adjustment in real exchange rates: towards a solution to the purchasing power parity puzzles. *International Economic Reviews*, 42(4), 1015–1042.

Trehan, B. (1986). Oil prices, exchange rate and the US economy. *Economic Review*, 4, 3-21.

Turhan, M. I., Sensoy, A., and Hacihasanoglu, E. (2014). A comparative analysis of the dynamic relationship between oil prices and exchange rates. *Journal of International Financial Markets, Institutions and Money*, 32(C), 397-414.

Yousefi, A., and Wirjanto, T. S. (2004). The empirical role of the exchange rate on the crude-oil price formation. *Energy Economics*, 26(5), 783-799.

Wright, J. (2008). Bayesian Model Averaging and exchange rate forecasts. *Journal of Econometrics*, 146(2), 329-341.

Zhang, Y.-J., Fan, Y., Tsai, H.-T., and Wei, Y.-M. (2008). Spillover effect of US dollar exchange rate on oil prices. *Journal of Policy Modeling*, 30(6), 973-991.

Zhang, Y.-J. (2013). The Links between the Price of Oil and the Value of US Dollar. *International Journal of Energy Economics and Policy*, 3(4), 2013, 341-351.

Appendix

Table A.1. Literature review

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Ahmad and Hernandez (2013); Journal of International Financial Markets, Institutions & Money	2013	TAR (threshold autoregressive) and M-TAR (momentum threshold autoregressive)	Real oil prices, real exchange rates, oil price: WTI and average of WTI, Brent and Dubai.	Fifteen largest oil producers and largest oil consumers in the world (excluding de facto fixed regimes): Brazil, Canada, Eurozone, India, Iran, Japan, South Korea, Mexico, Nigeria, Norway, UK, Venezuela	1970:01–2012:01 (monthly data)	Evidence for cointegration in six of the twelve countries studied and additional asymmetric adjustment in four countries of which Brazil, Nigeria and the UK show higher adjustment after a positive shock than after a negative shock. Real exchange rate appreciation following a rise in the real oil prices is eliminated faster than a depreciation following a fall in the real oil prices. (Opposite for the Eurozone)

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Akram; Econometrics Journal (2004)	2004	Non-linear econometric model - framework of Ozkan and Sutherland (1998), equilibrium correction model (EqCMs)	krone/ECU exchange rate index, oil price	Norway	1.1.1986 – 12.8.1998 (daily) The out-of sample: 1998:1 to 2000:4	Strong evidence for a non-linear negative relationship between the value of the Norwegian krone and crude oil prices (change in oil prices has a strong impact on the exchange rate when oil prices are particularly low, i.e. below 14 USD) Non-linear model outperforms the random walk model in out-of-sample forecasting of the exchange rate over a period of 12 quarters
Alquist et al. (2011)	2011	Comparison of different models (AR, ARMA, VAR, nonparametric models)	WTI crude oil price, oil futures, US refiners' acquisition costs, US Real GDP	USA	Out-of-sample: 1973:1 – 2009:12	The paper provides a vast overview on oil price forecasting addressing a wide range of different issues.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Altarturi et al. (2016); International Journal of Energy Economics and Policy	2016	Wavelet coherency e.g. CWT),	WTI crude oil price, exchange rate: log nominal effective OPEC currencies to USD)	OPEC	1999:02 – 2016:03 (daily data)	Countries with currencies pegged to USD are lagging against oil price changes, while countries with a floating exchange rate and countries with undisclosed weighted basket of international currencies lead changes in oil price.
Amano, van Norden (1998); Review of International Economics	1998	Johansen-Juselius cointegration test, Phillips and Hansen´s fully modified least-squares estimator (FMLS)	Morgan Guaranty 15-country real effective exchange rate. Domestic price of oil (US price of West Texas intermediate crude oil price index)	Germany, Japan, United States	In-Sample (s. S&C) 1973:01 – 1993:06 (monthly)	Rise in oil prices by 10% causes deprecation of Mark (0.9%) and Yen (1.7%) and an appreciation of USD (2.6%).
		Meese and Rogoff Methodology			Out-of-sample (updated Data to March 1995, using Meese and Rogoff´s methodology to forecast, beginning 1985)	Forecast based on oil prices perform better than random walk.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Amano, van Norden (1998); Journal of International Money and Finance	1998	Johansen-Juselius cointegration test, Single-equation error-correction model (ECM)	Real effective (i.e. trade-weighted) value of the US Dollar and US real price of oil (s.a.)	US	In sample: 1972:2 – 1993:01 (monthly)	Stabil long run link between oil prices and the US real effective exchange rate. Price of oil Granger-causes the exchange rate and not vice versa. (Higher prices leads to appreciation)
					Out-of-sample: 1985:12 – 1993:01	Single-equation has significant ability to predict EX changes out-of-sample.
Bal, Rath (2015); Energy Economics **See also: De Vita, Trachanas (2016).**	2015	Hiemstra and Jones (1994) nonlinear Granger causality test to the VAR residuals GARCH (1,1): robustness check	Real effective exchange rate (REER) of China (RXC) and India (RIX), Crude oil price (real terms and deflated by US CPI)	India, China	1994:01 – 2013:04 (monthly data)	Oil price do not linear Granger cause EXR (both countries). Significant bi-directional nonlinear Granger causality: lagged information from oil price influences the EXR and vice versa (India). China: EXR causes oil price (nonlinear and unidirectional).

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Basher, Haug and Sadorsky. (2012); Energy Economics	2012	Structural VAR model	Global oil production, oil prices (WTI), global real economic activity (index), EXR, MSCI emerging stock market index, interest rates (TED spread). Dummy (1) to capture Asian financial crises (Sept. 1998).	Emerging markets	1988:01 – 2008:12 (Monthly data)	EXR respond to movements in oil prices (short run). Positive oil price shock leads to a drop in trade-weighted exchange rate. No evidence for impact of EXR shocks on Oil price.
Basher, Haug and Sadorsky. (2016); Energy Economics	2016	SVAR, Markov-switching model	world oil supply, global real economic activity, oil prices, and exchange rates.	Exporting: Brazil, Canada, Mexico, Norway, Russia and the United Kingdom. Importing: India, Japan, South Korea	1976:02 – 2014:02 (monthly data)	Oil demand shock leads to significant exchange rate appreciation pressures in oil exporting economies. Only limited evidence that oil supply shocks affect exchange rates for either oil exporting or oil importing countries

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Beckmann, Czudaj (2013a); International Review of Economics and Finance	2013	Markov-switching vector error correction model (MS-VECM)	Trade-weighted nominal and real effective exchange, three different country indices (broad, main, OITP), WTI crude oil price (in USD/barrel), US CPI, three-month treasury bill rate.	US	1974:01 – 2011:11 (monthly data)	Effective depreciation of the dollar triggers an increase in oil Prices (in nominal terms). Increase in real oil prices is associated with a real appreciation of the dollar (stem from price effects).
Beckmann, Czudaj (2013b); Energy Economics	2013	Markov-switching vector error correction model (MS-VECM)	WTI nominal oil price expressed in USD, CPI and exchange rates of 12 oil exporting and importing countries against the US dollar	Oil exporting: Brazil, Canada, Mexico, Norway, Russia; Oil importing: Euro Area, India, Japan, South Africa, South Korea, Sweden, and the UK	1974:01 – 2011:12 (monthly data)	Most important causality runs from exchange rates to oil prices, with a depreciation of the dollar triggering an increase in oil prices. Nonlinearities are an important issue when analyzing oil prices.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Beckmann, Berger, Czudaj (2016); Quantitative Finance	2016	Static and dynamic copula approach	WTI nominal oil price expressed in USD and exchange rates of 12 oil exporting and importing countries against the US dollar	Oil exporting: Brazil, Canada, Mexico, Norway, Russia; Oil importing: Euro Area, India, Japan, South Africa, South Korea, Sweden, and the UK	2003:09 – 2013:09 (daily data)	The intensity of relationship between oil prices and FX-rates has increased over time and the increased tail dependency shows that extreme events are likelier to occur simultaneously for both variables. Currencies of oil importers and oil exporters display a different dependency structure against the US dollar in the case of rising oil prices with the latter appreciating and the former depreciating.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Bénassy-Quéré et al. (2007); Energy Policy	2007	Johansen (1988) and Johansen and Juselius Cointegration(1990), VECM	Dollar real effective exchange rate, real EXR against Euro (from 1978:12), oil price	US, Japan, China, Eurozone (theory)	1974:01- 2004:11 (monthly data)	Rise of oil price (10%) coincides with an appreciation of USD (4 3%) in the long run. Causality from Oil to Dollar. Slow adjustment speed (half-life deviation of about 6,5 years)
Benhmad (2012); Economic Modelling	2012	Wavelet approach (DTW: discrete wavelet transform).	Real oil price (average of Brent, WTI and Dubai Fateh), REER (USD),	US	1970:02 – 2010:02 (monthly data).	Strong bi-directional causal relationship between the real oil price and the real dollar exchange rate for large time horizons. But for the first frequency band (3-month) causality runs from oil price to exchange rate.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Bodart et al. (2012); Journal of International Money and Finance	2012	Unit root tests (LLC, IPS, INVN), panel cointegration tests following Fachin (2007), 3 panel cointegration techniques: fully modified OLS, dynamic OLS, BKN following Bai et al. (2009)	Real effective exchange rate, price of leading export commodity, with and without common time dummies	14 developing countries whose exports are highly concentrated on one specific commodity (>10%)	1980-2008	Price of the dominant commodity has a significant long-run impact on the real exchange rate when exports of the leading commodity contribute to at least 20% of total exports. The larger this share, the large the effect
Bouoiyour et al. (2015); Energy Economics	2015	ARDL bounds testing approach, wavelet coherence (WTC?), wavelet-based signal detection Frequency domain approach	Oil price, real exchange rate, GDP, government spending, terms of trade, productivity differential	Russia	1993Q1 – 2009Q4 (Quarterly data)	Oil price causes sharp real EXR in lower frequencies. The link between oil price and real exchange rate seems conditioning upon GDP, government expenditures, terms of trade and productivity differentia

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Chaban (2009); Journal of International Money and Finance	2009	Extension of Hau and Rey (2006) to commodity-producing countries with well-developed equity markets; structural VAR model addressing the simultaneity issue (three endogenous variables, exogenous commodity returns)	Exchange rate returns (dep. Variable), equity returns, commodity returns, equity flows	Australia, Canada, New Zealand	1980:01-2006:11 (monthly data) (Table 4: quarterly regression)	Compared to Hau and Rey (2006), the portfolio-rebalancing motive is weaker in the three countries. In contrast, positive correlation between equity returns and exchange rate returns and no significant correlation between equity flows and exchange rate returns. Possible explanation: positive equity return shock affects commodity-exporting countries via comm. Prices: less need to rebalance portfolios
Chaudhuri and Daniel (1998); Economic Letters	1998	Engel-Granger cointegration, ECM	Real EXR (foreign currency price of USD), real oil price (United Arab Emirates price of oil)	16 OCED countries	1973:01 – 1996:02 (monthly data) except It & SWE (end 1993:11),Belgium (1980:01 – 1996:03)	Real USD producer price EXR and real price of oil are cointegrated for the most industrial countries.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Chang (2014); North American Journal of Economics and Finance	2014	Symmetrized copula framework? 4000758	Crude oil (WTI), nominal exchange rate,	Australia, Canada New Zealand	4.1.1990 – 28.6.2016 (daily data)	Exceedance Correlations between oil and exchange rate returns are both positive and symmetrical
Chen and Chen (2007); Energy Economics	2007	Johansen, Panel cointegration techniques (Pedroni 2004?), FMOLS, DOLS, PMG (pooled mean group)	Real Oil Price (world oil price, United Arab emirates price, Brent, WTI) real exchange rate, CPI + implementing structural breaks,	G7 (Canada, France, Germany, Italy, Japan, UK, US)	1972:01 – 2005:10 (monthly data) in-sample (1972:01 – 1990:12) & out-of-sample	Cointegrated relationship between real oil prices and real exchange rates. Forecast based on oil prices perform better than those on random walk. Predictability is higher in the long run.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Chen, Rogoff and Rossi (2010); The Quarterly Journal of Economics	2010	In-sample BIVARIATE GRANGER-CAUSALITY TESTS , ANDREWS'S (1993) QLR TEST FOR INSTABILITIES and out-of-sample forecasting (AR)	dollar spot prices in the world commodity markets to construct country-specific, export-earnings-weighted commodity price indices; nominal effective exchange rates; Dow Jones–AIG Futures and Spot indices; forward price data from Bloomberg for a selected set of metal products—gold, silver, platinum, and copper—to compare with our exchange rate–based forecasts	Commodity Currencies Australia (from 1984:1 to 2008:1) Canada (from 1973:1 to 2008:1), Chile (from 1989:3 to 2008:1) New Zealand (from 1987:1 to 2008:1) South Africa (from 1994:1 to 2008:1).	In-Sample and out-of-sample	structural link between exchange rates and commodity prices through the terms-of-trade and income effects: Exchange rates are very useful in forecasting future commodity prices (causal interpretation: because approach is robust to parameter instabilities and because commodity prices are essentially exogenous to the exchange rates

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Coudert et al. (2008); Energy Studies Review	2008	Johansen (1988) and Johansen and Juselius (1990) Cointegration, VAR, BEER model	Real oil price, US effective exchange rate, (BEER: net foreign assets, terms of trade)	US	1974:01 – 2004:11 (monthly data)	Causality runs from Oil prices to EXR Increase in oil leads to appreciation of USD in the long run. Adjustment very slow (6.5 Years). Link (BEER model) through US net foreign asset position.
De Schryder and Peersman (2015); Energy Journal	2015	Oil demand model: panel error correction model (ECM), panel error correction test of Gengenbach, Urbain, Westerlund (2008), PANIC	Total oil consumption per capita, global real US dollar crude oil price, real GDP per capita, real US dollar effective exchange rate, linear time trend,	65 oil-importing countries that do not have the US dollar as their local	1971-2008	An appreciation of the US dollar exchange rate leads to a significant decline in oil demand. This effect is considerably larger than the impact of a shift in the global crude US dollar oil price which

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
		test (Bai and Ng 2002), Mean Group (MG) estimator and FE, PANIC decomposition to estimate common components in the residuals (adj. MG)	country-specific constant, common components of residuals of MG regression as proxy for omitted common variables	currency (23 OECD, 42 non-OECD countries)		may be a consequence of a stronger pass-through of changes in the US dollar exch. rate to domestic end-user oil product prices rel. to changes in global crude oil price
De Vita, Trachanas (2016); Energy Economics "A failed replication" – see Bal and Rath (2015)	2016	Ng and Perron Test (unit root), model see Bath and Rat (2015)	see Bath and Rat (2015)	India, China	1994:01 – 2013:04 (monthly data)	'Pure replication' and a 'reanalysis' of Bal and Rath (2015). Oil price is level stationary I(0). No evidence for nonlinear or cointegrated causality for India and China

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Ferraro, Rogoff and Rossi (2015), Journal of International Money and Finance	2015	"Pseudo" out-of-sample fit with realized fundamentals (commodity price model)	Canadian-USD nominal Exchange rate, spot price crude oil (WTI), Canadian and US interest rates,[13]	Canada	In Sample and out-of-Sample. 12/14/1984 to 11/05/2010 (daily , monthly and quarterly (end-of-sample)	Empirical results suggest that commodity prices can predict commodity currencies' exchange rates at a daily frequency, in the sense of having a stable "out-of-sample fit" relationship (not evident at quarterly and monthly frequencies).
Fratzscher, Schneider and van Robays (2014); ECB Working Paper Series	2014	structural six-variable VAR	effective dollar exchange rate, WTI crude oil price in USD, Dow Jones Ind. Avg. Index (US stock returns), US short-term interest rates (three-month Certificate of Deposit), proxy for risk and a proxy for the financialization of oil markets[14]		02.01.2001 – 19.10.2012 (daily data)	Bi-directional causality between the US dollar and oil prices since the early 2000s. Causality between oil prices and exchange rates runs negative in both directions. Oil prices and the US dollar are significantly affected by changes inequity market returns and risk

[13] In addition, we consider other currencies and commodities. The Norwegian krone-US, South African rand-US dollar and Australian Dollar-US dollar nominal exchange rates are from Barclays Bank International (BBI). The Chilean peso-US dollar exchange rate is from WM Reuters (WMR). Besides the oil price series described above, we use prices for copper and gold.

[14] Weekly open interest in the NYMEX oil futures market gathered by the Commodities Futures Trading Commission (CFTC)

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Ghosh (2011); Applied Energy	2011	GARCH and EGARCH model	Brent crude oil, rupee-dollar exchange rate in nominal terms. Daily returns on oil price and EXR.	India	2.7.2007 – 28.11.2008 (daily data)	Increase in the oil price return leads to a depreciation of Indian Rupee (to US Dollar). Positive and negative oil price shocks have similar effects, in terms of magnitude, on exchange rate volatility in India (symmetric effect).
Habib, Bützer and Stracca (2016); IMF Economic Review	2016	Two-stage approach: 1. Sign restriction identification scheme (VAR) 2. Fixed effects pooled panel model "first identify oil supply and demand shocks using a sign restrictions identification	REER, bilateral nominal EXR with USD, IMF Special Drawing Rights, CPI, stock market returns, interest rates (mainly money market), foreign exchange reserve, self-constructed EMP index (exchange market pressure), currency crisis	43 countries (12 advanced and 31 emerging)	1986:01 – 2013:12 (monthly and quarterly data)	Main Result: For the full set of 43 countries there is no systematic evidence of a relationship between the oil or the commodity trade balance and exchange rate movements following oil price shocks. Countries with a higher oil surplus

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
		scheme, and then condition exchange rates and other macro variables in each individual country to the shocks estimated in the first stage in a panel setting"	dummy, Oil price: US crude oil imported acquisition cost by Refiners denominated in SDR, oil trade balance (as share of GDP), commodity trade balance, Index of Industrial Production from OECD			tend to lean against appreciation pressures by accumulating foreign exchange reserves. In Countries with floating currencies nominal appreciation in the wake of oil demand shocks.
Huang and Guo (2007); China Economic Review	2007	Four-dimensional structural VAR (SVAR) model	Real world oil price, real industrial prod., REER (deflate nominal RNB by PPI), relative CPI	China	1990:01 – 2005:10 (monthly data)	Real oil price shock leads to minor appreciation of REER in the long run.
Husain et al. (2015); IMF Staff Discussion Note	2015					
Jawadi et al. (2016); Economic Modelling	2016	Continuous-time jump-diffusion model, GARCH	USD/EURO exchange rate.	US	2014:08 – 2016:01 (intraday data)	Negative relationship between the US dollar/euro and oil returns, indicating that a US$ appreciation decreases oil price. Further evidence for volatility spillover from the US exchange market to the oil market.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Jiang, Gu (2016); Physica A	2016	SVAR, multifractal detrended cross-correlation analysis (MF DCCA and MF-ADCCA, asymmetric,	world economic activity index, world oil production, WTI oil price, trade weighted US Dollar Index, bilateral exchange rates (between the US dollar and other currencies[15])	US (see currencies [13])	Exchange rate: 4. Jan. 2000 – 31. Dec. 2014 (daily data) Other variables: 1994:01 – 2014:12 (monthly data)	Cross-correlations between oil prices and exchange rates exist in the long run. Cross-correlations are multifractal: they are more persistent in small fluctuations than that in large fluctuations. MF-ADCCA : cross-correlations between oil prices and exchange rates are significantly asymmetric
Kohlscheen et al. (2016); BIS Working Paper	2016	First-differences, pseudo out-of-sample prediction (Meese and Rogoff 1983), compare	Nominal exchange rate, commodity export price	11 major commodity-exporting countries (Australia, Canada, Norway, Brazil,	In-sample and out-of-sample, 2004:01 – 2015:02 (daily data),	Economically and statistically significant link between commodity prices and exchange rates, even at high frequencies. This link

15 CAD/USD (Canada/US), MXN/USD (Mexico/US), NOK/USD (Norway/US), GBP/USD (UK/US), JPY/USD (Japan/US), AUD/USD (Australia/US), EUR/USD (EU/US), KRW/USD (Korea/US).

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
		MSPE of baseline model with that of pure random walk, DM test	index (CXPI), country FE, year dummies	Chile, Colombia, Mexico, Peru, South Africa, Russia, Malaysia)	Malaysia: 2005:08-2015:02, Russia: 2009:02-2015:02	remains unaffected when changes in uncertainty and risk appetite are considered. Implies that currency movements are not purely random
Narayan (2013); Journal of Asian Economics	2013	GLS-based time series predictive regression model (Westerlund and Narayan (2012))	Real oil price (Brent), real exchange rate,	14 Asian countries[16]	1990 – 2009 (monthly data) In-sample and out-of-sample	Oil price is an important predictor of exchange rates of Bangladesh, Cambodia, Hong Kong, and Vietnam vis-a` -vis the US dollar

[16] Importers: Japan, China, Hong Kong, Vietnam, Indonesia, the Philippines, Bangladesh and Cambodia. Exporters: India, Korea, Thailand, Singapore, and Malaysia

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Lizardo and Mollick (2010), Energy Economics	2010	VAR and VECM (?)	Oil price (WTI), nominal exchange rate (USD), US money supply (M1) relative to the foreign money supply, US industrial production (relative to foreign[17] Ind Prod.),	US (to other countries)	1975 – 2008:01? In sample and out-of-sample	Relationship between Oil price and US EXR (against major currencies) Increase in real oil price lead to significant depreciation of USD against net oil exporter currencies (Canada, Mexico, Russia) and to an appreciation against oil importers (e.g. Japan). Robustness exercises also show that oil price shocks are associated in the short-run with a decrease in the value of the USD relative to all currencies as well as to the trade weighted broad and major indexes

[17] Canada, Denmark, Euro Zone (Germany, France, Italy, Netherlands, Belgium/Luxembourg, Ireland, Spain, Austria, Finland, Portugal, Greece, and Slovenia), Japan, Norway, Mexico, Russia, Sweden, and the United Kingdom

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Pershin et al. (2016), Journal of Policy Modeling	2016	Johansen and Juselius (1990) cointegration (VAR)	Nominal EXR, crude oil prices - Brent, short term interbank interest rates (repo). (+ structural breaks)	Selected African countries: Botswana, Kenya Tanzania	01.12.2003 – 02.07.2014 (daily data)	No general rule. ?!?!
Rautava (2004), Journal of Comparative Economics	2004	VAR and VECM	Real GDP, real federal government revenues, REER of Ruble (endogenous variables), price of crude oil	Russia	1995:01 – 2002:04 (quarterly data)	XXXXXX
Reboredo (2012), Journal of Policy Modeling	2012	Marginal distribution model: TGARCH Copula models	EXR (USD per unit of foreign currency), Crude oil price in USD(WTI)	EU (EURO), Australia, Canada, UK, Japan, Norway, Mexico, TWEXB (US Federal Reserve's Broad Trade Weighted Exchange Index)	04.01.2000 – 15.06.2010 (daily data)	Increase in oil prices is weakly associated with USD depreciation and vice versa. Copula models: tail independence between oil prices and exchange rates in the periods before and after the financial crisis.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Reboredo and Rivera-Castro (2013); Economic Modelling	2013	Wavelet multi-resolution analysis	EXR(foreign currency per unit of USD), Crude oil price in USD (WTI)	EU (EURO), Australia, Canada, UK, Japan, Mexico, Norway, TWEXB	04.01.2000 – 07.10.2011 (daily data)	Oil prices and exchange rates were independent in the pre-crisis period. Evidence of contagion and negative dependence after the onset of the crisis. Oil prices led exchange rates and vice versa in the crisis period but not in the pre-crisis period
Tiwari et al. (2013a); Energy Economics.	2013	Discrete wavelet transform (DWT) approach and scale-by-scale Granger causality tests	Crude oil price (WTI), REER.	Romania	1986:02 – 2009:03 (monthly data)	Oil price have strong influence on the REER in the short run, but also for large time horizons.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Tiwari et al. (2013b); Economic Modelling	2013	Wavelet (DWT), non-linear causality tests.	Real oil price (WTI), REER (Rupee)	India	1993:04 – 2010:12 (monthly data)	Causal relationship between oil price and the real effective exchange detected at higher time scales (low frequency) but not at lower time (high frequency) scales. Unidirectional causality from exchange rates to oil prices at scale 16-32 month and bi-directional causality at scale 31-64 month.
Turhan et al. (2014); Journal of International Financial Markets, Institutions & Money	2014	Consistent dynamic conditional correlation model (cDCC),	Crude oil price Brent, Exchange rates (USD/ local currency)	G20, excluding Argentina, China and Saudi Arabia (controlled currency regime)	02/01/2000 - 17/04/2013 (daily data).	Link between oil prices and exchange rates has intensified in the last decade; they became strongly negatively correlated (which also associates an increase in the oil prices with the US dollar depreciation against other currencies.

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
						Two events related with significant shifts in the correlation levels e.g. Iraq-war 2003 and GFC (global financial crises) in 2008. No effect of ongoing Eurozone debt crises on oil price exchange rate correlation pattern.
Tiwari and Albulsecu (2016); Applied Energy	2016	Continuous wavelet approach (CWT), Markov regime-switching VAR (MRS-VAR), asymmetric multi-horizon Granger-causality test.	Oil price (Average of Brent, Dubai, and WTI), India-US real exchange rate	India	1980:01 – 2016:02 (monthly data)	Exchange rate Granger-causes the oil price in the long run. In the short run it's the opposite. The relationship is non-linear, asymmetric and indirect (exist only in the post-reform period).
Uddin et al. (2013); Economic Modelling	2013	Wavelet analysis: continuous wavelet transform (CWT) and Wavelet coherence (WTC).	REER (Real exchange rates), Real oil prices	Japan	1983:06 – 2013:05 (monthly and quarterly data)	Strength of co-movement regarding the return on the real effective exchange rate and oil price growth, differ and deviates over the time horizon

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Wang, Wu (2012); Economic Modelling	2012	Linear causality: VECM, Nonlinear: BDS test statistic, Diks and Panchenko (2006)'s nonlinear Granger causality test	crude oil, gasoline, heating oil and natural gas prices and trade-weighted exchange rates.	US	Jan. 2. 2003 – June 3. 2011 (daily data) (divided in 2 sup-periods (03—07;07-11)	After financial crises: bi-directional nonlinear causality between petroleum prices and exchange rate. Pre-crises: , unidirectional linear causality running from petroleum prices to exchange Rates.
Zhang et al. (2008); Journal of Policy Modeling	2008	VAR, (T)GARCH, VaR : Granger causality in risk, GED	Nominal prices: WTI crude oil price (USD/barrel), Spot (nominal) exchange rate of euro against dollar.	US	04.01.2000 – 31.05.2005	Mean Spillover: Significant long-term equilibrium cointegrating relationship can be identified between the two markets. This suggests a crucial reason for the fluctuation in crude oil price. Volatility spillover: No significant evidence Risk spillover: compared with the powerful oil market, the impact of US dollar exchange rate is confirmed to be relatively partial

Table A.1. Literature review (cont.)

Author / Year / Journal	Year	Methodology	Variables Included	Countries	In-sample / out-of sample	Result / Causality
Zhang (2013); International Journal of Energy Economics and Policy	2013	Engle-Granger (1987) residual-based cointegration test (ECM), Johansen and Juselius (1990) rank cointegration test.	Real crude oil price (WTI, deflated by US CPI), REER[18] of USD	US	1973:01 – 2010:06 (monthly data)	No cointegration of Oil price and the value of USD but considering **structural breaks** (1986 & 2005) existence of significant long run relationship.

[18] defined as the real trade-weighted value of the US dollar against the currencies of a broad group of major US trading partners (euro area, Canada, Japan, Mexico, China, United Kingdom, Taiwan, Korea, Singapore, Hong Kong, Malaysia, Brazil, Switzerland, Thailand, Philippines, Australia, Indonesia, India, Israel, Saudi Arabia, Russia, Sweden, Argentina, Venezuela, Chile, and Columbia).

Shortcuts:

Methodology	Variables
DWT: Discrete wavelet transform	BEER: Behavioral Equilibrium Exchange Rate
ECM: Error correction model	EMP Index: Exchange market pressure
EqCM: Equilibrium correction model	GFC: Global financial crises
FMLS: Fully modified least-squares estimator	REER: Real effective exchange rate
GARCH: Generalized autoregressive conditional	TED Spread: Treasury Bill Eurodollar Difference
heteroscedasticity TGARCH: Threshold GARCH,	OITP: Other important trading partners
EGARCH: Exponential GARCH	WTI: West Texas Intermediate crude oil price
GED: Generalized error distribution	
VaR: Value at Risk	
VAR: Vector auto regression	
SVAR: Structural VAR	