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A wavelet decomposition approach to crude oil price and exchange rate dependence

Juan C. Reboredo, Miguel A. Rivera-Castro *

Department of Economics, University of Santiago de Compostela, Avda. Xoán XXIII s/n, 15782 Santiago de Compostela, Spain

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ABSTRACT

This paper studies the relationship between oil prices and US dollar exchange rates using wavelet multi-resolution analysis. We characterized the oil price–exchange rate relationship for different timescales in an attempt to disentangle the possible existence of contagion and interdependence during the global financial crisis and analyze possible lead and lag effects. For crude oil prices and a range of currencies, we show that oil prices and exchange rates were not dependent in the pre-crisis period; however, we did find evidence of contagion and negative dependence after the onset of the crisis. Additionally, we found that oil prices led exchange rates and vice versa in the crisis period but not in the pre-crisis period. These findings have important implications for risk management, monetary policies to control oil inflationary pressures and fiscal policy in oil-exporting countries.

1. Introduction

Studying the link between oil and exchange rate markets is essential for many key financial and economic applications. Since the US dollar (USD) is the major invoicing and settlement currency in international oil markets, oscillations in the USD exchange rate affect both oil traders and oil-exporting and oil-importing countries. A weak USD increases the purchasing power of oil-importing countries (except the USA) but negatively affects oil-exporting countries. In contrast, an overvalued USD may adversely affect oil-importing countries and may cause a demand shock that ultimately affects oil-exporting countries. Likewise, joint movement between the oil and the USD exchange markets leads to investment and speculation opportunities and has implications for the pricing and hedging of currency and energy options (see, e.g., Salmon and Schleicher, 2007), the optimization of oil and currency portfolios (see, e.g., Beine, 2006) and energy and currency risk management (see, e.g., Marimoutou et al., 2009; Sadegui and Shavvalpour, 2006). Consequently, dependence between the oil and currency markets is of great interest for policy makers and investors.

In this article, we study oil and exchange rate market interdependence using wavelet multi-resolution analysis. Most of the empirical literature on oil–exchange rate dependence provides evidence in the time domain of the short- and long-range negative dependence and also provides evidence of oil–exchange rate co-movement (Reboredo, 2012), but evidence of the time and frequency domains has not, as yet, been provided.

The wavelet approach is model-free and permits study of the frequency components and time information in time series, in contrast with the standard time series econometric models, which consider only one or at most two time scales (the short and the long run) and rely on model parameters. An additional appealing feature of wavelet modeling is that the multi-resolution decomposition of the wavelet transform can be used to identify contagion and interdependence between markets. Shock transmission due to contagion is rapid and quickly fades; hence, in a matter of days, changes in wavelet correlations between time series at higher frequencies are associated with contagion, whereas changes at lower frequencies are associated with interdependence or co-movement (see Gallegati, 2012). Thus, the application of wavelets is useful to identify whether oil–exchange rate dependence changes in time under certain market conditions. More specifically, we tested the possible occurrence of financial market contagion and changes in interdependence between the crude oil and USD exchange rate markets during the recent global financial crisis using a test that consists of non-overlapping confidence intervals for the wavelet correlation coefficients at different time scales.

Furthermore, since theoretical models posit that investors tend to underreact to new public information in the short run and tend to overreact for longer horizons (Barberis et al., 1998; Daniel et al., 1998;

* Corresponding author.
E-mail addresses: juancarlos.reboredo@usc.es (J.C. Reboredo), marc@ufba.br (M.A. Rivera-Castro).

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Hong and Stein, 1999; Poteshman, 2001), we tested for lagged oil price effects on exchange rate returns and vice versa for different time scales using wavelet cross-correlations; in this way we could evaluate investor timing and verify the underreaction hypothesis.

Our empirical analysis focused on the relationship between crude oil prices and the USD exchange rate against a large set of currencies for the period January 2000 to October 2011. Empirical evidence reveals three new findings. First, oil price and exchange rate markets were independent in the period before the financial crisis, with near zero correlations for lower time scales and insignificant correlations for higher time scales. This evidence was common to all the USD exchange rates examined. Second, the wavelet correlations decreased significantly in the post-July 2008 period for all time scales, providing evidence of both contagion and increased (negative) interdependence between oil and exchange rate markets in the period after the onset of the global financial crisis. The fact that oil and exchange rate markets became more (negatively) dependent in the period after the onset of the financial crisis means that the diversification benefits of investors operating in those markets were considerably increased. Third, the wavelet cross-correlation analysis indicates that there was no market under- or overreaction in either of the two markets in the period before the financial crisis. However, with the onset of the financial crisis, oil prices led the USD exchange rate and vice versa for the higher frequencies, possibly as a result of the contagion effect. The situation was rather different for the lower frequencies, as oil and stock prices led each other in a complex manner and lead and lag correlations had both positive and negative significant values.

The rest of the paper is laid out as follows: Section 2 provides theoretical background and time series evidence on the relationship between oil prices and exchange rates. Section 3 introduces wavelet multi-resolution decomposition, the concepts of wavelet correlation and hypothesis testing. Sections 4 and 5 describe the data used in this research and our results, respectively. Section 6 discusses the implications of oil and exchange rate dependency and, finally, Section 7 concludes the paper.

2. Literature review

2.1. Theoretical background

The relationship between the USD and oil prices can be based on the law of one price: since oil is a fairly homogeneous and internationally traded commodity priced in USD, the oil price in foreign currency is given by:

$$p^* = e + p, \tag{1}$$

where p^* is the (log) oil price in units of foreign currency, p is the (log) oil price in USD and e is the (log) nominal USD exchange rate (foreign currency per unit of USD). Hence, USD depreciation (a reduction in e) reduces the oil price for foreigners relative to their commodities priced in foreign currencies, increasing thereby the purchasing power and oil demand of foreign consumers; this, in turn, pushes up the crude oil price in USD. From another point of view, Eq. (1) holds given that the arbitrage condition ensures that when the USD value drops, the oil price in USD rises and/or the oil price in foreign currency falls.

On the other hand, theoretical explanations of the impact of oil prices on the USD exchange rate were provided early on by Golub (1983) and Krugman (1983). Assuming that oil demand in oil-importing countries is inelastic, Golub argues that oil price rises have a wealth distribution effect in that they raise the current account surplus of oil exporters and the current account deficit of oil importing countries; they thus reduce expenditure on oil and the demand for USD. Krugman developed a theoretical model with speculation in which the effect of a rise in oil prices on exchange rates could be positive or negative depending on the relative benefits of the oil price movement on the balance of payments of oil exporters and importers. In the short run, an oil price increase will lead to dollar appreciation, but in the long run it will lead to dollar depreciation.

The impact of oil prices on exchange rates can be also explained on the basis of Eq. (1) for the price of any good. Taking a log-linear approximation of the home and foreign country consumer price indexes given by

$$p = (1-\phi)p^T + \phi p^N, \tag{2}$$

$$p^* = (1-\phi^*)p^{T^*} + \phi^* p^{N^*}, \tag{3}$$

where $p^T(p^{T*})$ and $p^N(p^{N*})$ are the prices of traded and nontraded goods for the home (foreign) country, respectively, and $\phi(\phi^*)$ is the weight corresponding to the expenditure share of nontraded goods in the home (foreign) country, the nominal exchange rate from Eq. (1) and Eqs. (2)–(3) can be expressed as:

$$e = \left(p^N - p^{N^*}\right) + (1-\phi^*)\left(p^{T^*} - p^{N^*}\right) - (1-\phi)\left(p^T - p^N\right). \tag{4}$$

Hence, assuming that $\phi \simeq \phi^*$ and the cost-push effect of an oil price change on nontraded goods is similar in the home and foreign countries, the effect of an oil price rise on exchange rates depends on its impact on the relative price of traded goods in the home country with respect to the relative price of traded goods in the foreign country. Thus, if the home country is more dependent on imported oil, an oil price rise could increase the relative prices of traded goods in the home country proportionally more than in the foreign country, thereby causing a depreciation in the home currency. Otherwise, the oil price rise causes the home currency to appreciate.

An alternative approach to the effect of oil prices on exchange rates comes from a monetary model of exchange rates. Assuming that the demand for money, m, depends on the price level, p, real income, y, and the interest rate, i, and that the effect of these variables on money demand is similar in the home and foreign country, then, from Eq. (1), for the prices of any good and the interest rate parity condition, we can express the nominal exchange rates:

$$e = (m^* - m) + (y - y^*). \tag{5}$$

Eq. (5) is a long-run monetary model of exchange rate determination that could accommodate oil price influence on exchange rates by considering oil prices as an additional explanatory variable (see, e.g., Lizardo and Mollick, 2010).

2.2. Empirical literature

The empirical literature has investigated the reciprocal influence between the USD exchange rate and the price of oil, generally finding a negative link between them.

Through the use of cointegration techniques, Amano and Norden (1998) and Camarero and Tamarit (2002)reported evidence of the role of oil prices in explaining the real exchange rate. Similarly, Akram (2004)reported evidence of a non-negative relationship between oil prices and the Norwegian exchange rate that varied with the oil price level. Taking monthly panel data for the G7 countries, Chen and Chen (2007)showed the dominant nature of real oil prices in real exchange rate movements and their significant forecasting power. Similarly, Cifarelli and Paladino (2010)reported evidence of a negative relationship between oil price shifts and exchange rate changes by employing a multivariate generalized autoregressive conditional heteroskedasticity-in-mean model. Adopting a monetary approach to exchange rate determination, Lizardo and Mollick (2010)showed the significant contribution of oil prices in explaining long-term USD movements, supporting thus a negative relationship between oil prices and the USD. In contrast, Huang and Guo (2007)found, using a four-dimensional structural vector