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Do oil prices respond to real interest rates?☆,☆☆

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ABSTRACT

We show that the robustness of an inverse relationship between the real interest rate and real oil price depends crucially on how the real interest rate is calculated, and the time-frame of the sample. Consistent with earlier studies, we find that the oil price falls with an unexpected rise in either U.S. or international ex-ante real interest rates. When the ex-post real interest rate is used, the oil price only falls with rises to short-term rates (3 months or less). Additionally, the response of the oil price to long-term ex-ante real interest rates must include the period through the mid-2000s for the inverse relationship to appear. In contrast, the oil price consistently falls with unexpected rises in short-term real interest rates throughout the entire sample. We draw two conclusions from the results. The first is that the oil price is consistently responsive to short-term U.S. and international real interest rates, underlying the importance of storage. Second, oil prices have become more responsive to long-term real interest rates over time.

1. Introduction

As summarized by Frankel (2006) and outlined in Hotelling (1931) and Working (1949), the real interest rate represents the opportunity cost of oil extraction and storage. A lower real interest rate results in reduced production and increased storage, and a higher real interest rate has the opposite impact. If these theories are correct, there should be an inverse relation between the real oil price and real interest rate.[1] Tests of either relationship have been numerous [see e.g. Deaton and Laroque (1992) and Slade and Thille (2009)], but have focused solely on the behavior of the real oil price and the peculiarities of either model.

This paper explicitly considers the response of the real oil price to movements in real interest rates. In doing so, it extends the results of other studies in several ways. Akram (2009) found that commodity prices generally, and oil prices in particular, increase with negative movements in U.S. real interest rates. He also showed that these real interest rate innovations account for a substantial portion of the forecast error variance in commodity prices. The results presented here show that both of these conclusions depend crucially on the calculation of the real interest rate and its term.[2] Unexpected rises in the ex-ante real interest rate lead to a fall in oil prices for both short (3 months or less) and long-term rates. However, unexpected rises to ex-post rates lead to this fall only with short-term real interest rates.

Frankel (2006) also finds an inverse relationship between the real interest rate and oil price using linear bivariate regression models estimated by ordinary least squares (OLS), although this relationship does not seem to hold after the 1980s. Frankel and Rose (2009) are unable to confirm a statistically significant inverse relationship between the oil price and real interest rate. Alquist et al. (2011) do not find a statistically significant relationship between the real interest rate and oil price either. The results given here show that the oil price responds inversely to movements in short-term rates consistently, however the response to long-term rates varies over time. In

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[1] The simplest form of the Hotelling Rule says that the price of oil, also the value of oil in the ground, should grow at an exogenously given rate of return. If we take this as the real interest rate and it rises, the oil producer will increase current production to match the change. This increasing of production will lower the price, all else equal. Similarly, if the real interest rate rises, the opportunity cost of storage does so as well. This induces less storage, reducing the demand for oil and lowering the price, all else equal.

[2] Ex-ante real interest rates are calculated by subtracting expected inflation over the following *x* months/years from the respective *x* month/year nominal rate. Ex-post rates come from subtracting observed inflation over the following *x* months/years from the *x* month/year nominal rate.

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particular, the sample must run through at least 2006 to generate the inverse response with long-term U.S. rates, and through 2008 with long-term international rates.[3]

These results are generated within a vector autoregressive (VAR) framework using both impulse responses and forecast error variance decompositions. In the simulations, the data have a monthly frequency, range from 1975M01 to 2012M05, and include OECD industrial production (*ip*), various measures of the real interest rate (*rint*), the effective U.S. real exchange rate (*rex*), and the real price of oil (*rpo*). The benchmark simulation uses the entire sample with an ex-ante one-year U.S. real interest rate. The ordering for this baseline simulation is: *ip*, *rint*, *rex*, and *rpo*. The impulse responses indicate that positive innovations in *rint* lead to a statistically significant instantaneous fall in *rpo*. In contrast with (Akram, 2009), we find that *rint* accounts for less than 5% of the one-month ahead variance in the forecast error of *rpo*. The magnitude of this impact also declines as the horizon becomes longer.

These results change dramatically if the ex-post U.S. real interest rate is used. In this case, increases in long-term rates do not lead to a fall in the oil price. The corresponding variance decomposition shows that the ex-post rate accounts for less than 4% of the forecast error variance in the first 4 months, but its importance increases over time. This changes again for short-term rates. In this case, positive innovations in the ex-post rate lead to a statistically significant fall in the oil price. The quantitative impact is also much larger. The ex-post real interest rate now accounts for almost 32% of the forecast error variance over 4 months, and this rises to just over 45% by 2 years.

The length of the sample is then varied. Impulse responses show that the oil price has responded inversely to unexpected movements in short-term U.S. real interest rates since at least 1988. This indicates that the relationship between these variables has not changed substantially over time. The relationship between long-term U.S. real interest rates and the oil price has changed. The sample must run through at least 2006 for the oil price to fall in response to a rise in long-term U.S. rates. Variance decomposition also shows that the fraction of the forecast error variance of the oil price accounted for by long-term U.S. rates begins to increase in 1999, and reaches 2% in 2006 when the relationship becomes statistically significant.

The U.S. real interest rate is used as a proxy for an international real interest rate, which would be more suitable given the global nature of the oil market. To gage the importance of this approximation, we next construct a different proxy using U.S. nominal interest rates and OECD inflation rates and re-evaluate our earlier conclusions. There are no substantial changes in our results, although we do find that in general the response of *rpo* is not as strong using this proxy. The sample must also run through 2008 for *rpo* to fall in response to unexpected movements in long-term international rates, and through 1989 for responses to short-term rates. All of our estimation results are robust to the frequency of the data, lag length, time trends, filtering, differencing of the oil price, type of oil price used, and adding explanatory variables.

We draw two conclusions from this exercise. The first is that the oil price is consistently responsive to short-term U.S. or international real interest rates, underlying the importance of storage for movements in the oil price. See Hamilton (2009) for more on this point. This may have important implications for the impact of U.S. monetary policy on oil prices as well (Krichene, 2006). It also supports the claims of Frankel (2006) and others that a lower federal funds rate can lead to higher oil prices. This assumes that a lower federal funds rate leads to a fall in the corresponding short-term rates, as is widely believed.[4]

Second, oil prices have become more responsive to long-term U.S. and international real interest rates after 2000. The mechanism for this change is not clear and requires further study. One possible explanation is that oil producers have started treating oil in the ground more like a conventional asset, as in the theory of Hotelling (1931). It seems plausible that below some threshold rate producers become more cognizant of the opportunity cost of investing in foreign securities. In particular, the rise of sovereign wealth funds for major oil exporters may contribute to producers considering oil among their whole class of assets and making production decisions accordingly.[5]

An alternative explanation is based on portfolio reallocation and the increased financialization of commodity markets in general, and the oil market in particular (Tang and Xiong, 2010). Facing low (and falling) global real interest rates, investors have moved out of other assets and into commodities, particularly oil futures. Ostensibly, the increased flows into the oil market have resulted in higher prices, thereby strengthening the inverse relationship.

2. Empirical model

A standard VAR representation is used to generate the results, which are summarized using impulse responses and forecast error variance decompositions. The impulse responses are encapsulated by a mean-zero moving average representation of a general VAR process:

$$\hat{y}_t = \sum_{j=0}^{\infty} \mathbf{B}_j \hat{u}_{t-j} \tag{1}$$

where $\hat{y}_t$ is an $N\times 1$ vector of variables, $\mathbf{B}_j$ are $N\times N$ matrices of coefficients, and the innovations $(\hat{u}_t)$ are $N\times 1$ white noise processes with $E\left(\hat{u}_t, \hat{u}_t^{'}\right) = \mathbf{S}_u$. The coefficient matrices ($\mathbf{B}_j$) encapsulate the responses of the variables to the respective innovations. Because $\mathbf{S}_u$ is not necessarily diagonal, the innovations may be correlated across equations in the same time period. As is well-known, this can make interpretation of impulse responses to innovations misleading, because co-movement with other variables is not taken into account.

An equivalent representation of the moving average process with orthogonal innovations can circumvent this issue. In this case the transformed innovations will be uncorrelated by construction, so that the variance–covariance matrix of the shocks is diagonal. The identity matrix is often chosen in this case, which amounts to finding an $N\times N$ matrix $\mathbf{G}^{-1}$ such that:

$$\mathbf{G}^{-1}\mathbf{S}_u\mathbf{G}^{'-1} = \mathbf{I} \tag{2}$$

where $\mathbf{I}$ is the $N\times N$ identity matrix. The orthogonal innovations are $\hat{\epsilon}_t = \hat{u}_t\mathbf{G}^{-1}$, so that $E(\hat{\epsilon}_t, \hat{\epsilon}_t) = \mathbf{G}^{-1}E(\hat{u}_t, \hat{u}_t)\mathbf{G}^{'-1} = \mathbf{I}$. These innovations are uncorrelated across both time and equations. The moving average representation with orthogonal innovations can be rewritten as:

$$\hat{y}_t = \sum_{j=0}^{\infty} \mathbf{A}_j \hat{\epsilon}_{t-j} \tag{3}$$

where $\mathbf{A}_j = \mathbf{G}^{-1}\mathbf{B}_j$. The elements of the $\mathbf{A}_j$ are interpreted as the responses of the system to the orthogonal innovations j periods ahead, meaning they encapsulate the impulse responses of variables to orthogonal innovations in each variable. It remains to find the elements of $\mathbf{G}$, which can be any solution to $\mathbf{G}\mathbf{G}^{'} = \mathbf{S}_u$. There are many

[3] For related studies see Anzuini et al. (2010), Arora and Tyers (2012), Arora (2011), Belke et al. (2010), Frankel (1986), and Reicher and Utlaut (2010).

[4] We do not test directly for monetary impacts here due to the well known issues with identification and ordering in our empirical framework, as shown by Cochrane (1994) and discussed in Anzuini et al. (2010).

[5] This explanation is also consistent with the well-discussed global savings glut theory. Returns on assets with similar risk structures were relatively low during the post-2000 period, which may have made producers more sensitive to rates.