The Relationship between Oil Prices, Exchange Rates and Interest Rates

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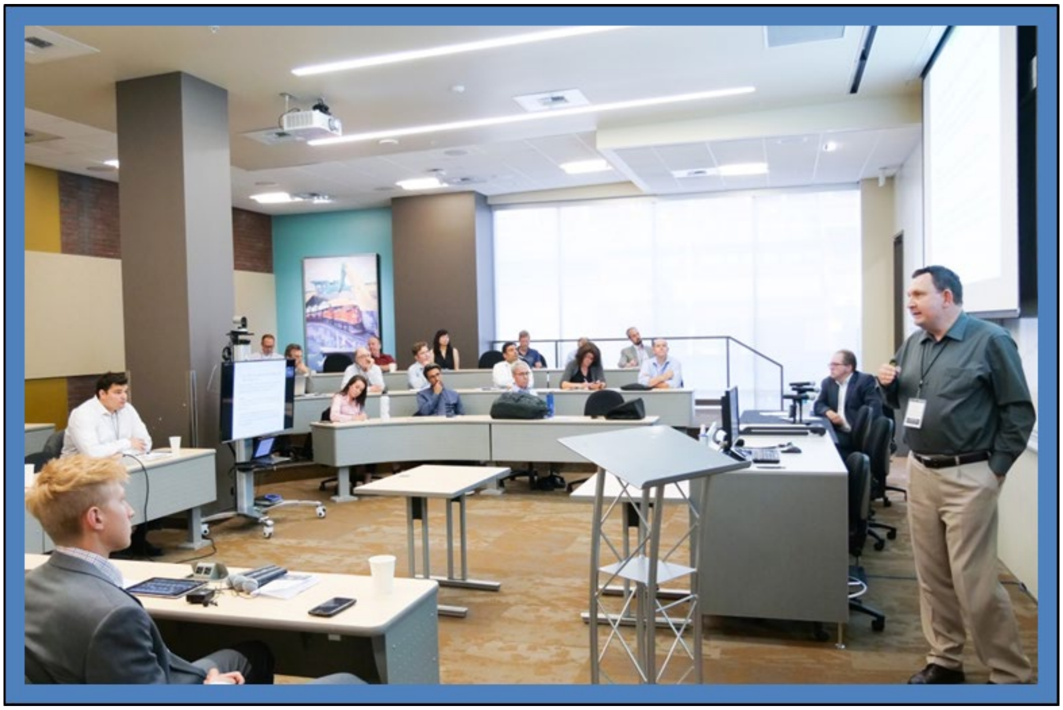


The co-author of this paper, **Dr. Lutz Kilian**, Ph.D., Senior Economic Policy Adviser, Federal Reserve Bank of Dallas, presented on "Oil Prices, Exchange Rates and Interest Rates" during a session on "Economics and Policy Issues on Energy Markets" at the JPMCC's 3rd Annual International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2019. Seated at the panel table is the chair of the session, Dr. Robert Vigfusson, Ph.D., Assistant Director and Chief, Trade and Quantitative Studies Section, International Finance, Board of Governors of the Federal Reserve System (Washington, D.C.). Both Dr. Kilian and Dr. Vigfusson are members of the JPMCC's Research Council.

Introduction

There has been much interest in the relationship between oil prices, exchange rates and interest rates since the 1980s. Even today, this relationship remains poorly understood, however. The challenge is that variation in any one of these variables tends to coincide with variation in the other variables, making it difficult to determine the ultimate cause of these fluctuations.

One popular argument in the literature has been that the real price of oil through its effect on the terms of trade is a primary determinant of the U.S. trade-weighted real exchange rate (Backus and Crucini 2000; Mundell 2002), but this conjecture has not been rigorously tested.

At the same time, the exact opposite argument has been made that exogenous fluctuations in the real exchange rate are driving the real price of oil. For example, there is a folk wisdom in the financial press that a depreciation of the dollar is associated with rising oil prices. The same sentiment is shared by many academics. Notably, Brown and Phillips (1986) conjectured that an exogenous appreciation of the U.S. real exchange rate in the early 1980s lowered the demand for oil outside the United States and stimulated the supply of oil, contributing to the fall in the real price of oil. Likewise, the sustained surge in the real price of oil in the 2000s has been attributed in part to the declining real value of the dollar.

A third argument, exemplified by Frankel (2014), is that fluctuations in the U.S. real interest rate affect the real price of oil not only by directly shifting the incentives for oil storage and production, but also by shifting the real exchange rate. This point is significant because it suggests that the real appreciation of the dollar and the decline in the real price of oil in the early 1980s may have been caused by higher U.S. real interest rates. Similarly, it has been suggested that the sustained surges in the real price of oil in 1979/80 and in the 2000s may be explained in part by low U.S. real interest rates, possibly caused by exogenous shifts in U.S. monetary policy.

Finally, to further complicate the analysis, it has been shown that the U.S. real interest rate responds to exogenous shifts in the demand for and supply of oil and, hence, so does the U.S. real exchange rate (Kilian and Lewis, 2011; Bodenstein *et al*., 2012). Thus, we cannot treat changes in the U.S. real interest rate as exogenous with respect to the real exchange rate and the real price of oil.

As this review illustrates, the three variables of interest are jointly and simultaneously determined. Thus, attempts to attribute causal effects to any one of these variables based on reduced-form correlations are doomed. Understanding cause and effect in the relationship between the real price of oil, the U.S. trade-weighted real exchange rate, and the U.S. real interest rate requires a structural model.

Generalizing the Workhorse Structural Oil Market Model

A recent study of ours proposes a novel approach to disentangling the causal effects of oil demand and oil supply shocks from the causal effects of shocks to the U.S. real exchange rate and the U.S. real interest rate (see Kilian and Zhou (2019)). In this study, we generalize the workhorse structural model of the global oil market, as discussed in Zhou (2019), to incorporate the trade-weighted U.S. real exchange rate and the U.S. real interest rate.

The model exploits three new insights. The first insight is that there cannot be feedback from exogenous variation in the U.S. exchange rate to the price of oil within the same month because, if there were, the price of oil would have a strong and statistically significant response to U.S. macroeconomic news much like the response found in the U.S. exchange rate. Kilian and Vega (2011) showed this not to be the case. The second insight is that longer-term market interest rates likewise are not contemporaneously affected by demand and supply shocks in the global oil market, which may be established in a similar manner. The third insight is that U.S. real market interest rates do not respond to exogenous changes in the real exchange rate on impact because expectations of inflation and output tend to be insensitive to exchange rate fluctuations in the short run.

Imposing these three restrictions on an otherwise standard model of the global oil market allows us to disentangle the causal effects of traditional oil demand and oil supply shocks from the causal effects of exogenous variation in the real exchange rate and the real interest rate without restricting the lagged interaction of the model variables.

The second co-author of this paper, **Dr. Xiaoqing Zhou**, Ph.D., Economist, Federal Reserve Bank of Dallas, also presented at the JPMCC's 3rd Annual International Commodities Symposium. Seated at the panel table is Dr. Zhou's co-author, Dr. Lutz Kilian, who, in turn, chaired the symposium's "Commodities Matter Everywhere" session.

Responses to U.S. Real Interest Rate Shocks

Our model allows us, for the first time, to quantify the effect of unexpected increases in the U.S. real interest rate on the real price of oil, building on the work of Frankel (2014). Some of the key implications of Frankel's model of real commodity prices may be summarized as follows:

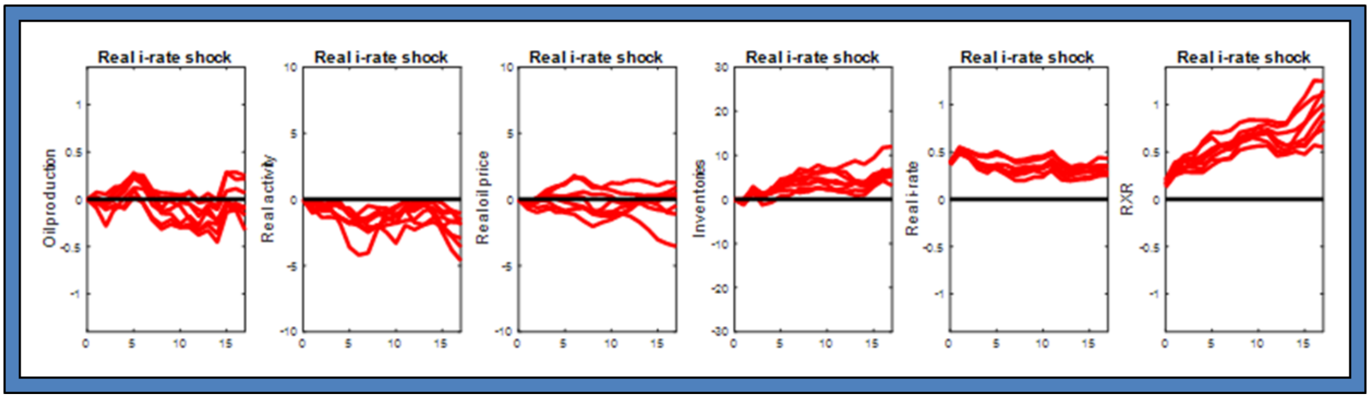
- An exogenous increase in the U.S. real interest rate stimulates global oil production by raising the opportunity cost of keeping oil below the ground. Frankel's model does not allow for the fact that higher U.S. real interest rates raise the capital cost of future oil extraction and hence may lower future oil production, however, which renders the sign of the oil production response ambiguous in practice, so we do not restrict this sign in our empirical analysis.

- Global real economic activity falls, as the value of the dollar appreciates in response to higher U.S. real interest rates.

- Finally, an exogenous increase in the U.S. real interest rate lowers oil inventories, as the opportunity cost of carrying inventories rises. Since the reduction in global real activity caused by higher U.S. real interest rates is likely to cause an accumulation of oil inventories, however, the sign of the inventory response is uncertain and hence is left unrestricted in our empirical work.

Thus, only the signs of the responses of the real exchange rate and of global real economic activity in Frankel's model are likely to be robust. Imposing the latter two sign restrictions on the structural model allows us to quantify the response of the real price of oil, in particular, to an exogenous increase in the U.S. real interest rate, as shown in Figure 1.

Figure 1
Responses to an Exogenous Increase in the U.S. Real Interest Rate



Notes: RXR stands for the trade-weighted U.S. real exchange rate and the real interest rate refers to the U.S. real market rate of interest. Real activity refers to global real economic activity and inventories to the level of global oil inventories.

Frankel's model implies that the real price of oil should fall in response to higher U.S. real interest rates. Figure 1 shows that the real price of oil indeed declines in the short run, as predicted, but at longer horizons the response is indistinguishable from zero. Thus, the response pattern is consistent with Frankel's model, allowing for the inherent ambiguity of the sign of the responses of oil production and oil stocks. However, even the most negative response of the real price of oil that is consistent with the data is small. This conclusion is robust to any additional restrictions one may impose.

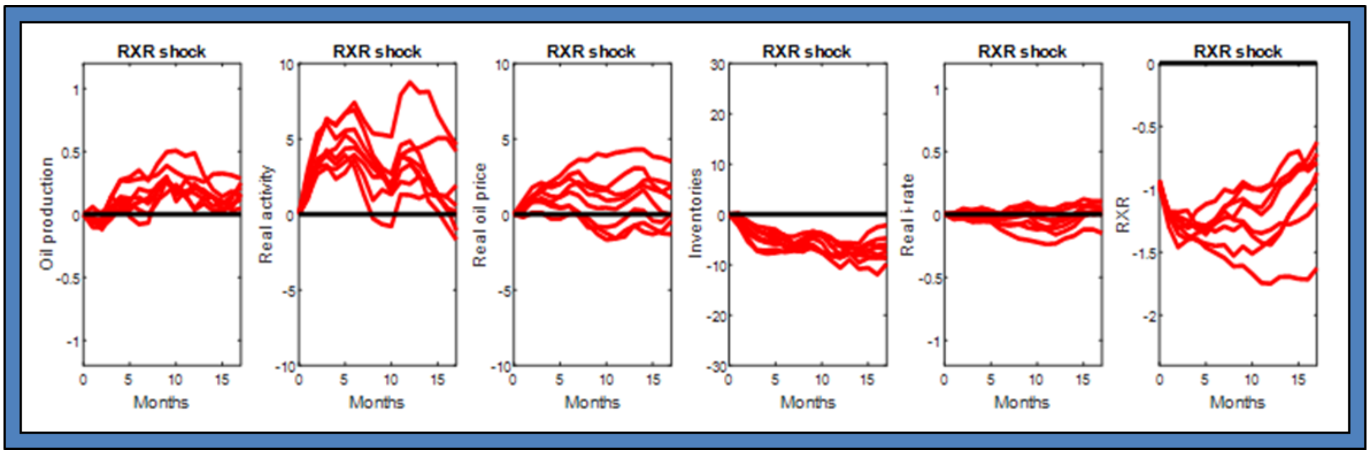
Responses to U.S. Real Exchange Rate Shocks

Next, we consider the responses to an exogenous real depreciation of the dollar in the same model. Figure 2 on the next page shows that the real price of oil tends to increase in the short run, as expected, but the magnitude of the response at longer horizons is indistinguishable from zero. Global real activity increases at least in the short run. The response of global oil production tends to be slightly positive with some delay, while that of the U.S. real interest rate and of oil stocks tends to be slightly negative. The latter three responses are again indistinguishable from zero.

Thus, from the point of view of the global oil market, real exchange rate shocks must be interpreted primarily as oil demand shocks. A real depreciation of the dollar, for example, makes it less expensive for countries other than the United States to import oil and other industrial commodities, raising global real activity and the real price of oil. A real appreciation, in contrast, tends to lower the real price of oil.

Our analysis provides direct evidence in support of a transmission of real exchange rate shocks to the real price of oil. In contrast, the responses of the U.S. trade-weighted real exchange rate to oil demand and oil supply shocks that raise the real price of oil are indistinguishable from zero in general (and hence are not shown), indicating that this link is weak and subject to great uncertainty.

Figure 2
Responses to an Exogenous Real Depreciation of the U.S. Dollar



The Key Determinants of the Variability in the Model Variables

Our structural model estimates shed light on a number of questions that have been debated in the literature for a long time. For example, Backus and Crucini (2000) conjectured that much of the variability of the real exchange rate reflects variability in the real price of oil, which traditionally had been viewed as being driven primarily by exogenous oil supply shocks. We are in a position to quantify the importance of exogenous oil demand and oil supply shocks for the variability of the U.S. real exchange rate (see Table 1 on the next page).

Our analysis provides no support for this conjecture. It reveals that exogenous oil supply shocks account, on average, for only 8% of the variability in the U.S. real exchange rate and all oil demand and oil supply shocks combined explain only about one third of the variability in the U.S. real exchange rate. The other two thirds are explained by exogenous variation in the real exchange rate (39%) and by exogenous variation in the U.S. real interest rate (26%).

The latter result supports the view that exogenous variation in the U.S. real interest rate is an important determinant of the real exchange rate (and hence of real commodity prices). Our model attributes about 10% of the variability in the real price of oil to exogenous U.S. real interest rate shocks and 16% to exogenous real exchange rate shocks, compared with 53% for traditional oil demand shocks and 10% for oil supply shocks.

The variability in the U.S. real interest rate, in contrast, is driven mainly by real interest rate shocks (39%) with real exchange rate shocks (10%) playing a lesser role. The relatively large contribution of oil demand shocks (29%) does not mean that the oil market is driving the U.S. real interest rate, but that both the oil market and the U.S. real interest rate are responding to the same global economic conditions.

Table 1
Variance Decompositions (Percent)

	Shocks				
	Flow Supply	Flow Demand	Storage Demand	Real Exchange Rate	Real Interest Rate
Real Price of Oil	10.2 (7.2)	31.1 (17.7)	22 (17.5)	16.2 (8.6)	12.3 (10.7)
U.S. Real Exchange Rate	8.3 (4.4)	12.7 (9.7)	10.3 (8.8)	39.1 (9.8)	25.9 (6.6)
U.S. Real Interest Rate	11.8 (6.4)	19.7 (14.1)	9.1 (6.3)	9.7 (5.6)	38.9 (11.7)

Note: Posterior mean (with posterior standard error in parentheses).

What Happened in the Early 1980s?

As we have already shown, much of the variation in the U.S. real exchange rate is exogenous with respect to the real price of oil. In fact, there is evidence of a large, but slow-moving cycle of exogenous real appreciations and real depreciations of the U.S. dollar. Thus, one would not expect real exchange rate shocks to explain sudden large increases or decreases in the real price of oil. Indeed, exogenous exchange rate shocks contributed only 1% to the surge in the real price of oil from 1979.1 to 1980.9, for example.

We establish, however, that the cumulative effect of real exchange rate shocks over several years can be sizable. Of particular interest in this context is the extent to which the prolonged exogenous real appreciation of the dollar in the early 1980s contributed to the decline in the real price of oil after 1980. Brown and Phillips (1986), among others, conjectured that this contribution was important. Our model shows that these shocks explain a cumulative decline in the real price of oil of 16% between 1980.10 and 1985.3, suggesting that Brown and Phillips (1986) had a valid point, although the quantitative importance of that point is perhaps less than one might have conjectured.[1]

The early 1980s are by no means a historical exception in this regard. Between 2002.1 and 2008.3, for example, exogenous real exchange rate shocks cumulatively raised the real price of oil by 42%, as the U.S. dollar depreciated over an extended period.

Revisiting the Historical Narrative of the Ups and Downs of the Real Price of Oil

As we have noted, even a small response of the real price of oil to a one-time shock may be consistent with substantial cumulative effects of this shock over time. Thus, we investigate in detail whether allowing for additional shocks to the U.S. real exchange rate and the U.S. real interest rate in the global oil market model changes the historical narrative of what caused the ups and downs in the real price of oil since the late 1970s.

Table 2 focuses on historical episodes of major oil price fluctuations including the Iranian Revolution (1979.1-1980.9), the outbreak of the Iran-Iraq War (1980.9-1980.12), the collapse of OPEC (1985.12-1986.12), the invasion of Kuwait (1990.1-1990.11), the oil price surge of the 2000s (2003.1-2008.6), the Great Recession (2008.6-2008.12), and the most recent major oil price decline (2014.6-2015.12). For each episode, it shows the cumulative effect of selected structural shocks on the real price of oil in the absence of other structural shocks.

Table 2
The Cumulative Effect of Selected Shocks on the Real Price of Oil by Episode (Percent)

	1979.1-1980.9	1980.9-1980.12	1985.12-1986.12	1990.1-1990.11	2003.1-2008.6	2008.6-2008.12	2014.6-2015.12
Flow Supply Shock	0.3	3.1	1.9	**12.4**	4.4	2.9	**-18**
Flow Demand Shock	23.2	-0.1	-21.2	**-4.1**	**64.9**	**-63.4**	**-26.8**
Storage Demand Shock	11.5	4.2	-16.2	**21**	-28.7	**-48.4**	**-37.1**
Real Interest Rate Shock	0.8	0.6	-13.7	-4.8	8.8	**-7.5**	-1.5
Real Exchange Rate Shock	1.1	0.4	-2.9	4.5	**50.4**	**-10.2**	-13.8

Notes: Posterior median. Boldface indicates precise estimates.

Table 2 shows that the main difference from earlier studies is the large cumulative effect of exogenous real exchange rate shocks during the oil price surge between 2003.1 and 2008.6. In fact, this is the only episode when these cumulative effects are both large and precisely estimated. While it remains true that flow demand shocks explain the bulk of this increase, as evidenced by a cumulative increase of 65%, higher demand for oil from the exogenous depreciation of the U.S. dollar explains an additional 50% cumulative increase in the real price of oil, making it the second most important determinant of the real price of oil. In traditional oil market models these shocks are conflated and virtually all of the increase in the real price of oil is attributed to flow demand shocks (Zhou, 2019).

In either case, however, the importance of oil demand shocks in this episode is much larger than that of oil supply shocks. Thus, extending the oil market model by including the U.S. real exchange rate and the U.S. real interest rate yields a more nuanced, but substantively similar conclusion about what happened during 2003.1-2008.6.

With this qualification, the substantive results are quite similar to earlier studies. For example, the surge in the real price of oil in 1979/80 was mainly caused by a combination of flow demand and storage demand shocks. The decline in the real price of oil in 1986 mainly reflected lower flow demand, as the global economy slowed, and lower storage demand, as OPEC's impotence to control the price of oil was revealed. The oil price spike of 1990 was caused by an oil supply disruption and a surge in storage demand, reflecting expectations of future shortages of oil. The sharp decline in the real price of oil in the second half of 2008 mainly reflected lower flow demand, as the global economy entered a recession, and lower storage demand, and the decline after June 2014 reflected a combination of positive oil supply shocks and negative oil demand shocks.

Monetary Policy and Commodity Prices

An important question for policymakers is whether the U.S. Federal Reserve was partially responsible for the surge in oil prices in 1979/80 and in the 2000s. One view has been that the U.S. Federal Reserve contributed to the commodity price boom between 2003 and 2008 by allowing the real interest rate to remain low for too long. Our model allows us to formally evaluate and reject this conjecture. Although real interest rate shocks in Table 2 account for a 9% increase in the real price of oil, that increase is dwarfed by the cumulative effect of flow demand and real exchange rate shocks of 115% combined over the same period. Moreover, the 68% credible set suggests that the cumulative effect of real interest rate shocks could be anywhere between -13% and +28%. Thus, there is no credible evidence that monetary policy was responsible for the sustained surge in the real price of oil after 2002. In contrast, the contribution of other structural shocks is larger and more precisely estimated. Likewise, Table 2 shows no support for the hypothesis that the 1979/80 oil price increase was caused by earlier unexpected reductions in the real interest rate.

Concluding Remarks

Modeling the relationship between oil prices, exchange rates and interest rates raises some interesting identification challenges. Recent research shows how the workhorse structural oil market VAR model may be modified to overcome these challenges. The resulting structural model sheds light on common conjectures about the determinants of the variability of the real exchange rate, the real price of oil, and the U.S. real interest rate. The model estimates provide a more nuanced understanding of historical oil price fluctuations, but substantively agree with earlier historical narratives. They reveal no evidence in support of a link from shifts in U.S. monetary policy to real oil price fluctuations. They do provide, however, for the first time, direct empirical support for some of the effects highlighted in Frankel's (2014) model of real commodity prices.

Endnotes

1 It should be noted that in a structural model omitting the real interest rate shock one would have obtained a much higher estimate of 32% for the cumulative decline in the real price of oil explained by exogenous exchange rate shocks, illustrating the importance of jointly modeling the real exchange rate and the real interest rate.

Dr. Kilian presented on this topic at the JPMCC's 3rd Annual International Commodities Symposium during the "Economics and Policy Issues on Energy Markets" session on August 12, 2019. The symposium, in turn, was organized by Professor Jian Yang, Ph.D., CFA, the J.P. Morgan Endowed Chair and JPMCC Research Director at the University of Colorado Denver Business School.

The views in this article are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of Dallas or the Federal Reserve System.

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Author Biography

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Lutz Kilian received his Ph.D. in Economics from the University of Pennsylvania and his M.A. in Development Banking from The American University. Before joining the Federal Reserve Bank of Dallas in 2019, he was a Professor of Economics at the

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