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The Impact of Oil Price Shocks on U.S. Bond Market Returns

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Wensheng Kang
Department of Economics, Kent State University

Ronald A. Ratti
School of Business, University of Western Sydney and
Centre for Applied Macroeconomic Analysis, ANU

Kyung Hwan Yoon
School of Business, University of Western Sydney

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Keywords

Demand shocks, Oil prices, Bond returns, Supply shocks

JEL Classification

E44, G12, Q43

Address for correspondence:

(E) cama.admin@anu.edu.au

The Impact of Oil Price Shocks on U.S. Bond Market Returns

by

Wensheng Kang[a*], Ronald A. Ratti[b,c], Kyung Hwan Yoon[b]

[a]Department of Economics, Kent State University, Ohio, USA
[b]School of Business, University of Western Sydney, NSW, Australia
[c]Centre for Applied Macroeconomic Analysis, Australian National University, Australia

Abstract

This paper examines the effect of the demand and supply shocks driving the global crude oil market on aggregate U.S. bond index real returns. A positive oil market-specific demand shock is associated with significant decreases in aggregate bond index real returns for 8 months following the shock. A positive innovation in aggregate demand has a negative effect on real bond return that is statistically significant and becomes more adverse over 24 months. Structural shocks driving the global oil market jointly account for 27.1% of the variation in real bond returns at 24 month horizon. A spillover index from rolling SVAR models is used to identify the interdependence between the oil market and bond returns. The mean for this spillover index is 0.381 over 2001:01-2011:12 and 0.476 over September through December 2008 during the height of the global financial crisis.

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[*]Corresponding author:
wkang3@kent.edu
Department of Economics
Kent State University,Ohio, USA
Phone: 1-330-308-7414

The Impact of Oil Price Shocks on U.S. Bond Market Returns

1. Introduction

A considerable amount of research has focused on identifying the interaction between oil prices and stock markets. Early work gave conflicting results on the connection between oil price and stock returns. Chen et al. (1986) and Huang et al. (1996) do not find significant connections between oil price and oil price futures and U.S. stock returns, but Jones and Kaul (1996) find that oil price increases in the post war period have a significantly negative effect on aggregate stock returns. In recent years it has been noted that it is important to identify the source of oil price shocks when examining their impact on real stock returns. Kilian and Park (2009) show that U.S. real stock returns are adversely affected by positive oil market-specific demand shocks, but increases in global aggregate demand have a positive effect on real stock returns.

In this paper we examine the effect of the demand and supply shocks driving the global crude oil market on the U.S. real bond index returns. In contrast to work investigating the connection between oil prices and stock market returns, comparatively little attention has directly concentrated on the relationship between oil prices and bond market returns. Stock and bond markets are of comparable size in the functioning of the global financial system. US stock market capitalization stands at about 21.4 trillion U.S. dollars in early 2012, at which time the value of the U.S. bond market is valued at close to $37 trillion US dollars (Bloomberg). Outside the US, debt market capitalization exceeds equity market capitalization by a larger relative amount than in U.S. markets. Given the crucial position of the bond market in the financial system it is important to understand the connection between structural oil market shocks and real returns in the bond market.

We utilize a structural vector autoregression (SVAR) model to investigate how the demand and supply shocks driving the global crude oil market affect real bond returns. It is found that a positive oil market-specific demand shock is associated with significant decreases in a broad based U.S. bond index returns for 8 months after which time effects become insignificant and are eroded over the next 6 months. A positive innovation in global aggregate demand also has a negative effect on real bond return, but the effect is statistically significant over 24 months and becomes more adverse over time. The adverse effect is about 1% after 12 months. This result contrasts with the established result in the literature that a positive innovation in global aggregate demand is associated with increases in real stock returns.[1] The opposite response patterns of bond versus stock returns to global aggregate demand shocks show the importance of identifying the source of oil price shocks when examining their transmission to the price of bonds that are a natural hedge against stocks.

Our aggregate analysis also indicates that, on average, in the long run, shocks to the global crude oil market play an important role affecting the U.S. bond market. The demand and supply shocks driving the global crude oil market jointly account for 30.6% of the long-run variation in real returns for a broad based U.S. bond index with average maturity of five years. The large statistically significant predictive ability of the structural oil price shocks for aggregate bond index real returns is found to hold across corporate

[1] Kilian and Park (2009) argue the positive relationship between stock returns and aggregate demand shocks has been driven primarily by the stimulating effects of strong global demand for industrial commodities during 1975-2006.

and different fixed-term government bond indices. The structural oil price shocks jointly account for 28.2% of the long-run variation in real returns for a U.S. corporate bond index.

We find that shocks to oil-market specific demand explain 31.2% of the variation in the real 30-day Treasury-bill return in the long-run. Shocks to oil-market specific demand explain 24.4%, 13.2%, 11.1% and 16.1% of the variation in the real returns for 1-year, 5-year 10-year, and 30-year government bond indices in the long run. The dominant effects on the short-term Treasuary-bill return are associated with the literature that addresses the connection between oil prices and monetary policy as reflected in the response in short-term interest rates (by Bernanke et al. (1997) and others). On the other hand, we find that the adverse effect on real bond returns of positive shocks to global aggregate demand is more marked the greater is bond maturity.

The key finding of Kilian (2009) that oil price shocks vary with different signs at different points in time implies that the oil- and bond-market spillovers may be very different conditionally at any given point in time. We contribute to the literature by presenting the rolling sample analysis to investigate the dynamics of the effect of the structural oil price shocks on bond market returns over time. The summary spillover index of the connectedness of oil and bond markets is highly statistically significant. Rolling sample analysis indicates that the degree of spillover between the demand and supply shocks driving the global crude oil market and bond market return is especially high over the years 2008-2011, when economic activity slowed down significantly because of financial crisis and the post-crisis anemic recovery. The mean spillover index for the structural shocks in the global crude oil market and aggregate bond index real returns calculated from rolling SVAR models is 0.380 over 2001:01-2011:12 and 0.470 over September and October 2008. These results suggest that investors believe that bond holdings have value as a hedging instrument in recession, when decreased real oil prices and stock market fall are likely associated with increased real bond returns.

The paper is organized as follows. A brief literature review is provided in Section 2. Section 3 presents the methodology and the structural VAR model. Section 4 describes data sources. Section 5 discusses empirical results about the dynamics of oil price shocks and real bond returns. The robustness of results is discussed in Section 6. Section 7 concludes.

2. Literature Review

Hamilton (2008) notes that main channel by which energy price shocks influence aggregate economic activity is through effects on consumer and business spending on other goods and services. Bernanke (2006) argues that energy prices affect aggregate activity primarily through effects on consumer spending. This is consistent with work by Lee and Ni (2002) showing that oil price shocks primarily influence activity at industry level through demand side effects.

In recent years it has been noted that it is important to identify the source of oil price shocks when examining their impact on real economic activities and consumer prices. Kilian (2009) shows that positive oil-market specific demand shocks lower real GDP growth and raise CPI inflation, whereas oil price inceases associated with increases in global aggregate demand have a negative effect on GDP growth with a delay. Oil supply disruptions are found to cause a temporary decline in real GDP and have little effect on the price level. Hamilton (2009) distinguishes oil price shocks due to demand

and supply side influences. Global demand for oil in recent decades has been driven by rapid growth in major developing economies. Supply side influence is captured by changes in world oil production. It is thus recognized as crucial to identify the source of the oil price change in examining the effects of movement in oil price on real variables.

The importance of identifying the source of the oil price change in examining the effect of oil prices on stock returns has been confirmed in the literature. Filis et al. (2011), Basher et al. (2012) and Abhyankar et al. (2014) find that positive oil price shocks due to aggregate (oil market-specific) demand factors increase (decrease) stock returns. Degiannakis et al. (2014) find that aggregate demand driven oil price changes reduce stock market return volatility and that the other shocks are not significant. Apergis and Miller (2009) report that structural shocks have influence on stock returns, but that the magnitude of the effect is small. Wang et al. (2013) and Park and Ratti (2008) note that it is also important to distinguish between the effect of oil price shocks on the stock markets of oil importing and exporting countries.

Unlike studies on the effect of oil prices on real activity and stock markets, little work has been done on the effect of oil prices on bond markets. An issue connected to the relationship of structural oil market shocks with real bond market returns, the connection between oil prices and monetary policy as reflected in the response in short-term interest rates, has been addressed in the literature (by Bernanke et al. (1997) and others). Kilian and Lewis (2011) argue that there is little evidence of systematic policy responses to oil price shocks because oil price changes have different causes.

3. Methodology

Oil price shocks cause unanticipated changes in discretionary income and in precautionary saving and can thus influence returns in the bond market through influencing the demand for bonds by investors. Kilian and Park (2009) argue that an upturn in the global business cycle simultaneously promotes recovery in the U.S. economy and pushes up the real price of oil (which tends to offset the rise in U.S. economic activity). Kilian and Park (2009) find positive innovations to global aggregate demand have a positive effect on U.S. real stock returns despite oil prices being higher than expected. In response to a positive innovation to global aggregate demand, the stimulating effect on oil prices and on stocks is likely associated with falling net real aggregate demand for bonds and declining aggregate bond index real returns.

U.S. real stock returns are found to be adversely affected by the positive oil market-specific demand shocks (by Kilian and Park (2009) and others). This effect is found by controlling for global aggregate demand and is associated with increases in the real price of oil based on a precautionary concern for the stability of future oil supplies. The effect of an increase in real price due to a positive innovation in oil market-specific demand for oil may cause uncertain investors to move out of both stocks and bonds. Thus, it is hypothesized that aggregate bond index real returns decline with a positive oil market-specific demand shock. The likely divergent (similar) responses of real bond return and real stock return to shocks to global aggregate (oil-market specific) demand highlights the significance of isolating the source of oil price changes when predicting effects on financial markets.

A structural VAR model is used to separate the three structural oil price shocks - shocks to world oil supply, shocks to global aggregate demand for all commodities and oil market-specific demand shocks - and to assess their relationship with real bond returns. The structural representation of the VAR model of order p is

$$A_0 y_t = c_0 + \sum_{i=1}^{p} A_i y_{t-i} + \varepsilon_t, \quad (1)$$

where $y_t = (\Delta prod_t, rea_t, rpo_t, ret_t)$ is a 4×1 vector of endogenous variables, A_0 denotes the 4×4 contemporaneous coefficient matrix, c_0 represents a 4×1 vector of constant terms, A_i refers to the 4×4 autoregressive coefficient matrices, and ε_t stands for a 4×1 vector of structural disturbances. The endogenous variables in the model are the percent change in world oil production ($\Delta prod_t$), real global aggegate demand for all industrial commodities (rea_t), real prices of oil (rpo_t), and the real bond market returns (ret_t).[2]

We follow Kilian (2009) and Kilian and Park (2009) and take $p = 24$. The long lag of 24 months allows for a potentially long-delay in effects of structural oil price shocks on the economy and for a sufficient number of lags to remove serial correlation. The previous literature has shown that long lags are important in structural models of the global oil market to account for the low frequency co-movement between the real price of oil and global economic activity. Hamilton and Herrera (2004) emphasize the importance of allowing for long lags in evaluating the impact of oil price shocks on real activity. Sims (1998) and Sims et al. (1990) argue that even variables that display no inertia do not necessarily show absence of long lags in regressions on other variables.

[2] Real global aggregate demand for all industrial commodities is given by freight rates for bulk dry commodity cargoes deflated by the US consumer price index, linearly de-trended to remove effects of technological advances in ship building and long-term trends in demand for sea transport.

The reduced form VAR is obtained by multiplying both sides of Equation (1) with A_0^{-1} which is assumed to have a recursive structure such that the reduced form errors e_t are linear combinations of the structural errors ε_t in the following,

$$e_t = \begin{bmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \\ e_t^{ret} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{\Delta prod} \\ \varepsilon_t^{rea} \\ \varepsilon_t^{rpo} \\ \varepsilon_t^{ret} \end{bmatrix}, \quad (2)$$

in which $\varepsilon_t^{\Delta prod}$ reflects the oil supply-side shock, ε_t^{rea} captures the aggregate demand shock, ε_t^{rpo} denotes the oil market-specific demand shock, and ε_t^{ret} is the bond market shock.

The identifying restrictions on A_0^{-1} are motivated by Kilian (2009). The economic intuition is that crude oil supply does not respond to contemporaneous changes in oil demand within a given month because of the high adjustment cost of production in the oil market. Fluctuation in the real price of oil will not affect global real economic activity within a given month due to the sluggishness of the global real economic reaction. The model ordering the real bond return after oil price shocks is motivated by Kilian and Vega (2011) who argue that oil prices are predetermined with respect to U.S. macroeconomic aggregates within a given month.

In Equation (2) $e_t \sim N(0, \Sigma)$ in the reduced-form VAR model and the partial correlation coefficients quantifying the contemporaneous correlation between two components of the errors, $\rho_{ij} = -\sigma^{ij} / \sqrt{\delta^{ii}\delta^{jj}}$, where σ^{ij} denotes the elements of the precision matrix Σ^{-1}, are [3]

$$\begin{bmatrix} & rea & rpo & ret \\ \Delta prod & -0.005 & -0.031 & -0.003 \\ & (0.05) & (0.33) & (0.03) \\ rea & & 0.206 & -0.080 \\ & & (2.07) & (0.92) \\ rpo & & & -0.061 \\ & & & (0.73) \end{bmatrix}.$$

The result provides us with supporting evidence on the identifying restrictions on A_0^{-1} in the structual VAR model, in that the contemporaneous correlation between oil price shocks and real bond returns is small and statistically nonsignificant at the 1% significant level within a given month.[4] The stationarity of the variables in the structural VAR model is discussed in the Appendix.

4. Data

The study utilizes monthly data on the crude oil market and real U.S. bond market returns over 1982:01-2011:12. World production of crude oil, as a proxy for world oil supply, and U.S. refiner's acquisition cost of imported crude oil, as a proxy for price of oil, are from the U.S. Department of Energy. The percent change in world oil production is measured by $100\times$ the log differences in the world oil production in millions of barrels pumped per day averaged by month. The real price of oil is the nominal price of oil deflated by the U.S. CPI from the Bureau of Labor Statistics. Global real aggregate demand is measured by the index of global real economic activity constructed by Kilian

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[3] Values in the parenthesis of the matrix are absolute t-statistic to which the standard error is generated by recursive-design wild bootstrap with 2,000 replications proposed by Gonçalves and Kilian (2004).
[4] Swanson and Granger (1997) suggest using the value of partial correlation coefficients to determine the variable ordering and relevant t-statistics for identifying restriction on the VAR models.

(2009).[5] The index of real aggregate demand is based on the equal-weighted dry cargo freight rates. An increase in this index indicates a higher demand for shipping services arising from increases in real economic activity of the world. An advantage of the measure is that it includes activity in emerging economies such as China and India that are excluded from conventional measures of global economic activity based on OECD countries.

Real bond returns will be constructed for an index of aggregate bond holdings. The real aggregate U.S. bond market return is measured by Barclays' capital aggregate bond index returns deflated by the U.S. CPI. The Barclays' broad-based benchmark measure is an intermediate term index that includes U.S. dollar-denominated Treasury securities, government-related securities and investment grade corporate bonds.[6] The index has an average maturity about 5 years.

For comparison and robustness analysis, real returns will also be constructed for fixed-term indexes of single U.S. Treasury issues at fixed maturity horizons, and for a corporate bond index. The real return on fixed-term indexes of 30-day, 1-year, 5-year, 10-year, and 30-year U.S. Treasury securities are constructed by deflating by the U.S. CPI. The data on fixed-term indexes of U.S. Treasury securities are from CRSP.[7] The U.S. corporate bond index is from Barclays' and reflects the prices of investment grade, U.S. dollar denominated, fixed rate and taxable corporate bonds publicly issued in the

[5] The data are available at Kilian's webpage: http://www-personal.umich.edu/~lkilian/paperlinks.html.
[6] Barclays' U.S. aggregate bond index factsheet is available at https://indices.barcap.com/index.dxml.
[7] Fixed-Term Indexes are available in nine groups with 30-year, 20-year, 10-year, 7-year, 5-year, 2-year, 1-year, 90-day and 30-day target maturity. An issue that best represents each term is chosen at the end of each month and held through the next month for each of the fixed-term periods. The securities are fully taxable, non-callable and non-flower bonds.

U.S. The index has an average maturity of about 5 years. The real return on the corporate bond index is constructed by deflating by the U.S. CPI.

Information on aggregate real bond return, real price of crude oil and real stock return are shown in Figure 1.[8] The sharp declines in real oil prices as a result of slowed economic activity in industrial countries in the early 1980s and as a result of global financial crisis in 2008-2009 coincide with large movement in real bond returns. For example in late 2008, decreased real oil prices and stock market fall are associated with increased real bond returns, suggesting that bond holdings likely have value as a hedging instrument in recession. Expected inflation rates over the next 5 years are also shown in Figure 1. The expected rate of inflation over next 5 years is obtained from the Federal Reserve Bank of Cleveland.[9] It can be seen that the rate of expected inflation over a 5 year horizon decreases steady from 6.2% to 1.5% over past 30 years.

5. Empirical Results

5.1. U.S. aggregate real bond return

5.1.1. Responses to structural shocks

Figure 2 shows impulse responses of world oil production, global real economic activity, real oil price and the U.S. aggregate real bond return to one-standard deviation structural shocks for the forecast horizons up to 24 months. One-standard error and two-standard error bands indicated by dashed and dotted lines, respectively, are computed by conducting recursive-design wild bootstrap with 2,000 replications proposed by Gonçalves and Kilian (2004). All structural shocks have been normalized to represent a

[8] The U.S. stock market index is a value-weighted market portfolio including NYSE, AMEX and Nasdaq stocks from CRSP.
[9] The expected rate of inflation: http://www.clevelandfed.org/research/data/inflation_expectations/.

one standard deviation shock. To construct the structural VAR model representation, the reduced-form VAR model is consistently estimated using the least-squares method.

In column (1) of Figure 2, shocks to unexpected oil supply disruption cause an instantaneous negative effect on world oil production that is persistent and highly statistically significant. However, this shock has small and insignificant effect on the global real economic activity, real oil price and real bond return. Real economic activity declines for several months, real oil price increases over twenty months, and real bond return tends to increase over a fifteen month period in response to an unexpected oil supply disruption.[10]

In contrast, the two oil demand shocks have larger and more persistent effects on the real economy. First, as shown in column (2) of Figure 2 aggregate demand shocks caused by unexpected increases in global demand for all industrial commodities cause a large persistent and statistically significant increase in real economic activity. The response reaches its peak at 8% within a month, followed by a declining trend and stabilizes after about fifteen months. This shock causes persistent increases in the real price of oil that are statistically significant over the entire forecast horizon. It adversely affects the real bond return from the 1st through the 24th month. The negative effect is rising in absolute value over time (about 1% after 12 months), and is statistically significant over virtually the entire horizon. This result is notable because it captures the opposite effects of shocks to global aggregate demand on real stock and real bond returns. It has been noted, beginning with Kilian and Park (2009) and subsequently confirmed by

[10] Shocks to the world oil production do not have significant effects on real stock returns and are not as important in explaining real stock returns as shocks to global aggregate demand and oil market-specific demand shocks.

others, unanticipated positive innovations in global aggregate demand are associated with increases in real stock returns.

Second, a positive oil market-specific demand shock causes increases in global real economic activity in the first three months, but the effect declines sharply after three months as shown in column (3) of Figure 2. This positive innovation has a statistically significantly positive effect on real oil prices over 15 months. The effect quickly peaks to about 3% at 3 months and then slowly erodes over time. It also predicts a decrease in real bond returns that reaches its maximum at about 0.5% after about four months and is then followed by an erosion of the effect after 15 months.

The fourth column of Figure 2 reports the impulse response effects of shocks to the bond market. Innovations in the bond market have small and statistically insignificant effects on oil supply and the real price of oil. A positive shock to the bond market predicts increases in global real economic activity initially, followed by a reversal of that increase after 4 month. This positive shock causes an immediate increase in the real bond return of over 1% that is highly statistically significant over the entire horizon.

In summary, the results show that oil price shocks to oil market-specific demand and global aggregate demand cause significantly decreased real bond returns. The significant effect of oil price shocks due to oil market-specific demand on bond market returns (about 0.5%) lasts for nine months and is eroded after 15 months. Oil price increases associated with rises in global aggregate demand have a negative effect on bond market returns over 24 months. The adverse effect is about 1% after 12 months.

5.1.2. Variance decompositions

Decomposition of the forecast error variance of the percent contribution of the structural shocks in the oil market to the variation of the aggregate bond index real returns is reported in Table 1. Panel A of Table 1 reports the forecast error variance decompositions (FEVDs) of the real bond returns to shocks to world oil supply, global aggregate demand, and oil market-specific demand. It quantifies how important the three structural oil-price shocks have been on average for U.S. bond market returns. In the first few months the effects of three structural oil price shocks on the aggregate bond index real returns are negligible. Over time the explanatory power of the structural oil shocks increases. After 24 months, 8.2%, 9.3% and 9.6% of the variation in the real bond returns is accounted for by the innovations of world oil production, global aggregate demand and oil market-specific demand, respectively. These estimates are statistically significant and sum to 27.1% of the total variation in the real bond returns. Over a 60 month horizon, the sum of the FEVDs of the real bond returns to structural shocks in the oil market remains high at 30.6%. These results indicate that shocks to the global crude oil market play an important role in affecting real return in the U.S. bond market.

A summary measure of interdependence of the three oil price shocks and the real bond return is shown in Panel B of Table 1. We follow Diebold and Yilmaz (2009, 2013) to report the spillover table/index from the variance decomposition associated with all four variables in the VAR model. The spillover index is used to identify the interdependence between the oil market and the index of bond returns. The spillover table presents variance decompositions associated with all variables in the VAR model and the spillover index aggregates the interdependence effects across these variables to reveal the spillover trends, cycles and bursts into a single measure for a given forecast horizon.

Robustness check shows similar results when we perform some variations on the analysis with respect to the rolling window width the forecast horizon, and the ordering of the VAR.

In Panel B of Table 1, the off-diagonal elements show the 24-step ahead forecast error variances of a variable upon shocks to another variable.[11] The spillover index for the structural oil price shocks and real bond market return is given by $(1/4)\times$ the sum of off-diagonal elements. The spillover index at the 24 month horizon is 0.263 and is highly statistically significant, suggesting that spillovers on average are important in the global oil market and U.S. bond market.

5.1.3. Rolling sample analysis

The key finding of Kilian (2009) is that oil price shocks vary with different signs at different points in time. It implies that the oil-bond spillovers may be very different conditionally at any given point in time. Therefore, in this subsection we present rolling sample analysis to investigate the dynamics of the effect of the structural oil price shocks on bond market returns over time. There have been substantial changes in real oil price over the sample as well as the global financial crisis in recent years. Real oil prices have been much higher and more volatile over the last half of 2001:01-2011:12. The index for real price of crude oil rose from 24.37 in January 2007 to 58.32 in July 2008. In line with the global financial crisis and the weak global economy the real price of crude oil falls to 16.84 in January 2009. However, the real price of crude oil has recovered to 50.48 in April 2011 while global economic activity remains weak.

[11] New information in Panel B, Table 1 includes the observation that a shock to real bond return predicts a statistically significant 10.1% of the variation in world oil production. A shock to real bond return also forecasts 12.9% and 3.3% of the variation in global aggregate demand and oil market-specific demand, but the results are not statistically significant.

The rolling sample analysis will allow us to assess the extent and nature of change in decomposition of the forecast error variance in real bond return for each of the structural oil market shocks starting in January 2001. We estimate the structural VAR model using 228-month rolling samples. The first sample uses data over 1982:01-2000:12, the second sample uses data over 1982:02-2001:01, etc., with each subsequent sample adding one new month and dropping the first month of the data in the preceding sample.

Figure 3 reports the dynamic contributions to the variation of real bond returns from innovations in world oil supply, global aggregate demand, and oil market-specific demand at the 24-month-ahead forecast horizon over 2001:01-2011:12. In Figure 3 the effect of oil market-specific demand for oil on the variation in real bond return spikes dramatically at the end of 2008 as the global financial crisis plays out. Real global aggregate demand also has a pronounced increase in effect on variation in real bond return at the end 2008 and into 2009 as the real economy declines with the impact and onset of the global financial crisis. The effect of shocks to world oil supply on variation in real bond return seems to be on a slowly declining trend over the 11 year period.

Figure 4 presents the spillover index calculated from the rolling SVAR model. Over 2001:01-2011:12 the mean spillover index calculated from the rolling SVAR model is 0.381, which is higher than the value of 0.263 for the spillover index calculated from a SVAR for the whole sample 1982:01-2011:12 (reported in Table 1). It can be seen that the spillover index rises in months following a major historical event. The spillover index upticks at the time of Hurricane Katrina in 2005:8, following sharp oil price changes in financial crisis over 2008:7-2008:12 and in the Arab Spring in 2011:1. The spillover index in Figure 4 is especially high over September through December 2008 (0.476) during the global financial crises and over January and February 2011 (0.485) during the Arab Spring.

5.2. U.S. corporate and government real bond return

In this subsection we examine how structual oil price shocks affect real returns of U.S. corporate bond index and fixed-term indices of U.S. Treasury securities. This will establish the robustness results for the aggregate index and allow assessment of whether results differ greatly by type and maturity of bond.

5.2.1. U.S. corporate real bond return

The forecast error variance decompositions of real U.S. investment grade corporate bond market returns to the structural shocks appear in Table 2. Shocks to world oil supply, global aggregate demand and oil market-specific demand account for a statistically significant 6.9%, 11.2% and 10.1%, respectively, of the total variation in the real corporate bond returns, or 28.2% combined. Results are similar to those for the U.S. aggregate real bond return noted in the previous section. The average maturity of the U.S. corporate bond and the U.S. aggregate bond portfolios are both about five years.

5.2.2. U.S. government real bond return by maturity

The forecast error variance decompositions of real returns in fixed-term indices of U.S. Treasury securities with maturities of 30-day, 1-year, 5-year, 10-year, and 30-year appear in Table 3. In Panel A of Table 3, shocks to oil-market specific demand explain 31.2% of the variation in the real 30-day Treasury-bill return. In Panel B of Table 3, shocks to oil-market specific demand explain 24.4% of the variation in the real 1-year governmentbond return. In Panels C, D and E of Table 3, oil-market specific demand explains much smaller fractions of the long-term variation in the real returns for 5-year, 10-year, and 30-year government bond indices (13.2%, 11.1% and 16.1%).

5.2.3. Responses of U.S. government real bond return by maturity

In this subsection we turn to examine how different the responses of real bond returns to structural oil price shocks are by maturity. This analysis helps address effects of oil shocks on the slope of yield curve, in the sense that the impulse response estimates assess the timing and magnitude of responses of real bond returns with maturity that are closely associated with the prediction on short-term and long-term interest rates.

Figure 5 shows the responses of real returns in fixed-term indices of U.S. Treasury securities with maturities of 30-day, 1-year, 5-year, 10-year, and 30-year to one-standard deviation structural oil price shocks for the forecast horizons up to 24 months. A negative shock to world oil supply significantly lowers the real return on 30-day T-bill, more so as time goes on. Possibly short-term interest decreases over time with oil supply restrictions. A negative effect is also apparent for real return on 1-year government bond, but the effect is marginally significant. For longer maturities shocks to world oil supply do not significantly affect real return. The finding of a negative effect on real returns for shorter fixed-term indices of U.S. Treasury securities is consistent with the observation by Kilian and Park (2009) of evidence that the Federal Reserve lowers interest rates in response to oil supply disruptions.

The effect of a positive shock to aggregate demand has a significant negative effect on real bond return for 5-year and longer maturity bond indices and the adverse effect is more pronounced over time. Given that bonds are a natural hedge against stocks, the finding that real returns on longer fixed-term indices of U.S. Treasury securities fall with a positive shock to global aggregate demand may be consistent with the finding in the literature that real stock returns rise in response to a positive innovation to global aggregate demand.

A positive oil market-specific demand shock causes statistically significant decreases in real bond returns. The length of time of the statistical significance of the decline in real bond return to positive oil market-specific demand shocks is declining in maturity of the bond index. The negative effect on the real return of the 30-day T-bill persists over the entire horizon. The negative effect of a positive oil market-specific demand is statistically significant for the real return of the 1-year, 5-year, 10-year and 30-year maturity bond indices for 8, 6, 5 and 4 months respectively. This negative effect on real bond returns in the short term is likely associated with future higher short-term interest rates.[12]

6. Robustness of results

In this section we examine the robustness of results to the introduction of expected inflation into the VAR model to variation in lag length. In equation (1) the vector of endogenous variables becomes $y_t = (\Delta prod_t, rea_t, rpo_t, ei_t, ret_t)$, where ei_t is expected U.S. inflation over next 5 years (from the Federal Reserve Bank of Cleveland) and ret_t is the U.S. aggregate bond index returns (with an average maturity of five years). This analysis guards against possible factors omitted from the model, if the impulse reponse functions and forecast error variance decompositions are not substantially changed by adding the expected U.S. inflation in the structural VAR model.

[12] Kilian and Park (2009) observe that the Federal Reserve raises the Federal Fund rate in response to positive oil market-specific demand shocks, but that this explains only a fraction of the variation in short-term interest rates.

Figure 6 shows the responses of global oil production, real economic activity, real price of oil, expected inflation, and the real bond market return to one-standard deviation structural shocks, for horizons up to 24 months. The focus here will be on results with regard to expected inflation. In column (1) of Figure 6, shocks to unexpected oil supply disruption causes increases in expected inflation that are statistically significant after 20 months. In column (2) of Figure 6, an unanticipated innovation in aggregate demand is associated with persistent increases in expected inflation that are statistically significant over most of the horizon. Since this is coupled with a positive innovation in aggregate demand adversely affecting the real bond market return from the 1st through the 24th month, it appears that increases in nominal bond return attendant on positive innovation in aggregate demand are not sufficient to offset increases in expected inflation.[13]

In the third column of Figure 6, positive oil market specific demand shocks increase expected inflation and decrease real bond return significantly in the first 5 months, followed by a reversal of these changes within the first year. An unanticipated increase in expected inflation results in a decline in real economy activity that is statistically significant over most of the horizon in column 4 of Figure 6. This shock causes decreases in the real prices of oil within the first year and causes little changes in the global oil supply. A positive shock to expected inflation predicts decreases in real bond market returns in the first two months and then increases in real bond returns after 2 months for an extended period of time. In the last column of Figure 6 innovations in real

[13] In results not reported, if nominal bond return replaces real bond return in the VAR, positive innovation in aggregate demand is associated with statistically insignificant declines in nominal bond returns over the 24 month horizon. Also positive oil market specific demand shocks decrease real bond return insignificantly in the first 6 months, followed by a reversal of these changes within the first year. Results are available from the authors upon request.

bond returns causes a decline in expected inflation and a rise in real bond market returns that are highly statistically significant from the 1st through the 18th month.

We now examine the robustness of results with regard to lag length. The results are similar for the model $y_t = (\Delta prod_t, rea_t, rpo_t, ei_t, ret_t)$ with expected inflation in the model with 12 lags, and for the model $y_t = (\Delta prod_t, rea_t, rpo_t, ret_t)$ without expected inflation in the model with 12 lags. The statistical significance of the impulse responses is relatively lower, but the results remain statistically significant. In Figure 7, in the models with 12 lags, positive innovation in aggregate demand is associated with statistically significant declines in real bond returns over most of the 24 month horizon. Also positive oil market specific demand shocks decrease real bond return significantly in the first 6 months, followed by a reversal of these changes within the first year. Results are robust to lag length being either 12 or 24 months.

Table 4 reports the forecast error variance decompositions of the real bond market returns for the expanded model $y_t = (\Delta prod_t, rea_t, rpo_t, ei_t, ret_t)$ that includes expected inflation. After 24 months, 9.4%, 6.4% and 9.6% of the variation in the real bond market returns are accounted for by the innovations of oil supply, aggregate demand and precautionary demand respectively. These estimates are statistically significant and sum to 25.4% of the total variation in the real bond market returns. Over a 60 month horizon, the sum of the FEVDs of the real bond returns to structural shocks in the oil market remains high at more than 28.0% after 60 months. The total spillover index for structural oil market shocks, expected inflation and real bond returns at 60 months is 46.0% at a high level of statistical significance. To summarize, the results with expected inflation in the SVAR model do not greatly alter the findings of the effects of the structural oil market shocks on real bond returns reported earlier.

7. Conclusion

This paper utilizes a structural VAR model to analyze how real bond returns react to specific supply and demand shocks in the oil market. A positive oil market-specific demand shock causes a significant decline in real bond index returns for 8 months after which time effects become insignificant and are eroded over the next 6 months. A positive innovation in global aggregate demand causes a negative effect on real bond return that is statistically significant over 24 months and becomes more adverse over time.

The demand and supply shocks driving the global crude oil market jointly account for 30.6% of the long-run variation in real returns for a broad based U.S. bond index with average maturity of five years. Structural oil market shocks have significant predictive ability for real bond returns across U.S. corporate and different fixed-term U.S. government bond indices. The structural oil price shocks jointly account for 28.2% of the long-run variation in real returns for a U.S. corporate bond index with average maturity of about five years. Overall, results for forecast error variance decompositions for real returns of investment grade U.S. corporate bonds and indices of U.S. government bonds are similar in response to the structural shocks from the crude oil market. This is especially true for the 5-year and 10-year government bond indices real return responses in comparison to the real return response of corporate bonds.

The effect on real bond return volatility of variation in global aggegate demand and oil market-specific demand are of approximate size and somewhat larger than the effect of variation in world oil supply for corporate and government bond indixes with maturity of average maturity of five or ten years. For shorter term maturities it is found that shocks to oil-market specific demand explain 31.2% (24.4%) of the variation in the real 30-day Treasury-bill (1-year government bond index) return. The predictive power at the 60 month horizon of all three structural oil price shocks for variation in the real return for all of the bond indices considered are statistically significant.

Given that bonds that are a natural hedge against stocks, the finding that the stimulating effect of positive innovations to global aggregate demand is negative for U.S. aggregate bond index real returns is consistent with the finding in the literature that U.S. real stock returns decline in response to a positive innovation to global aggregate demand. A positive shocks to global aggregate demand has a negative and long-lived effect on real bond returns of more than 24 months.

It is found that oil-market specific demand has a negative effect on U.S. real bond returns over about 8 months. This result, together with the finding in the literature that U.S. real stock returns are also adversely affected by a positive oil market-specific demand shock, suggests that investors move out of both stocks and bonds when there is increased uncertainty regarding the stability of future oil supplies that raises the real oil price.

The opposite responses of real bond return (down) and real stock return (up) to positive shocks to global aggregate demand, and the qualitatively similar responses (down) of real bond and real stock returns to positive shocks to oil-market specific demand, underlines the importance of identifying the source of oil price changes when examining their transmission to the real economy and financial markets.

The summary spillover index of the connectedness of oil and bond markets is statistically significant. Rolling sample analysis indicates that the degree of spillover between the oil and bond markets is especially high over the years 2008-2011. The mean spillover index for oil price shocks and aggregate bond index real returns calculated from rolling SVAR models is 0.380 over 2001:01-2011:12 and 0.476 over September and October 2008 during the height of the global financial crisis.

Appendix

The stationarity of the variables in the structural VAR model is investigated by conducting Augmented Dicky-Fuller (ADF), Phillips-Perron (PP) Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests for each series. Test results are reported in Table A1. We find that we can reject the null hypothesis, based on the ADF test, that $\Delta prod_t$, rea_t, rpo_t and ret_t contain a unit root at the 5% significant level, but we find that the PP test suggests that real price of oil (rpo_t) contains a unit root. Outcomes are mostly symmetric; the null of a unit root is dismissed for all series except real oil price at the 5% level in both tests. This would be expected as the Phillips-Perron has the same power properties as the ADF test. Because both tests lack power it is possible that the failure to reject the null in one case, the real price of oil is simply a type II error. Employing two tests with the same power and size properties will not enhance the properties of either and it could be argued that the ADF Generalised Least Squares test might be more powerful. However, failure to reject the null in this one variable is not decisive for the model.

The KPSS has the null hypothesis that the series is stationary. The KPSS does not reject the hypotheses that the percent change in global crude oil production and the real bond market index return are stationary. However, the stationarity of real economic aggregate activity index and the real price of oil are rejected. The nonstationarity of the real price of oil may lead to a loss of asymptotic efficiency reflected in a wider error bands in the estimation. However, differencing the real price series results in removal of the slow moving component in the series, and incorrectly differencing the real price of oil would cause the estimates to be inconsistent given the nature of standard unit root tests (e.g., Abhyankar et al. (2013), Kilian and Murphy (2013)). Since the estimated impulse response is robust even if the stationary assumption is violated, we use the level of the real price of oil as in common with prior literature (e.g., Kilian (2009) and Kilian and Park (2009)).

References

Abhyabkar, A., B. Xu, and J. Wang (2013), “Oil price shocks and the stock market: evidence from Japan,” *The Energy Journal*, 34, 199-222.

Apergis, N. and Miller, S.M. (2009), “Do structural oil-market shocks affect stock prices?” *Energy Economics*, 31, 569-575.

Basher, S.A., A.A. Haug, P. Sadorsky (2012), “Oil prices, exchange rates and emerging stock markets,” *Energy Economics*, 34, 227-240.

Bernanke, B.S. (2006), “Energy and the economy,” speech on June 15, Economic Club of Chicago.

Bernanke, B.S., Gertler, M., and Watson, M. (1997), "Systematic monetary policy and the effects of oil price shocks," *Brookings Papers on Economic Activity* 28, 91-157.

Chen, N.F., Roll, R. and Ross, S. (1986), “Economic forces and the stock market,” *Journal of Business*, 59, 383-403.

Degiannakis, S., Filis, G. and Kizys, R. (2014), “The effects of oil price shocks on stock market volatility: evidence from European data.” *The Energy Journal*, 35, 35-56.

Diebold, F.X. and K. Yilmaz (2009), "Measuring financial asset return and volatility spillovers, with application to global equity markets," *Economic Journal*, 119, 158-171.

Diebold, F.X. and K. Yilmaz (2013), "On the network topology of variance decompositions: measuring the connectedness of financial firms," *Journal of Econometrics*, forthcoming.

Filis, G., Degiannakis, S. and Floros, C. (2011), “Dynamic correlation between stock market and oil prices: The case of oil-importing and oil-exporting countries,” *International Review of Financial Analysis*, 20, 152-164.

Gonçalves, S. and L. Kilian (2004), “Bootstrapping autoregressions with conditional heteroskedasticity of unknown form,” *Journal of Econometrics*, 123, 89-120.

Hamilton, J.D. (2008), “Oil and the macroeconomy,” in S. Durlauf and L. Blume (eds), The New Palgrave Dictionary of Economics, 2nd ed., Palgrave MacMillan Ltd.

Hamilton, J.D. (2009), “Causes and consequences of the oil shock of 2007-08,” *Brookings Papers on Economic Activity*, Spring, 215-261.

Hamilton, J.D. and Herrera, A.M. (2004), “Oil Shocks and Aggregate Macroeconomic Behavior: The Role of Monetary Policy,” *Journal of Money, Credit, and Banking*, 36, 265-86.

Huang, Roger D., Masulis, R.W. and H. R. Stoll (1996), "Energy shocks and financial markets," *Journal of Futures Markets* 16, 1-27.

Jones, C.M. and Kaul, G. (1996), “Oil and the stock markets,” *Journal of Finance*, 51, 463-491.

Kilian, L. (2009), “Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market,” *American Economic Review*, 99, 1053-1069.

Kilian, L. and L.T. Lewis (2011), “Does the Fed respond to oil price shocks?” *The Economic Journal*, 121, 1047-1072.

Kilian, L. and D.P. Murphy (2013), “The role of inventories and speculative trading in the global market for crude oil,” *Journal of Applied Economics*, forthcoming.

Kilian, L. and C. Park (2009), “The impact of oil price shocks on the U.S. stock market,” *International Economic Review*, 50, 1267-1287.

Kilian L. and C. Vega (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, 660-671.

Lee, K. and S. Ni, (2002), “On the dynamic effects of oil price shocks: a study using industry level data,” *Journal of Monetary Economics*, 49(4), 823-852.

Park, J. and R.A. Ratti (2008), “Oil prices and stock markets in the U.S. and 13 European countries,” *Energy Economics*, 30, 2587-2608.

Sims, C.A. (1998), "Econometric implications of the government budget constraint," *Journal of Econometrics*, 83, 9-19.

Sims, C.A., J.H. Stock and M. Watson (1990), “Inference in linear time-series models with some unit roots,” *Econometrica*, 58, 113-144.

Swanson, N.R. and C.W.J. Granger (1997), “Impulse response functions based on a causal approach to residual orthogonalization in vector autoregressions,” *Journal of American Statistical Association*, 92, 357-367.

Wang, Y., Wua, C., and Y. Li (2013), “Oil price shocks and stock market activities: Evidence from oil-importing and oil-exporting countries,” *Journal of Comparative Economics*, 41 (4), 1220–1239.

Table A1. Unite Root Test

	ADF Test		PP Test		KPSS Test	
Variables	Without Trent	With Trent	Without Trent	With Trent	Without Trent	With Trent
$\Delta prod_t$	-11.837 ***	-11.840 ***	-18.830 ***	-18.803 ***	0.015	0.015
rea_t	-2.965 ***	-3.723 ***	-3.088 ***	-3.711 ***	3.100 ***	0.394 ***
rpo_t	-2.049 **	-2.679	-1.805	-2.452	2.570 ***	1.710 ***
ret_t	-8.400 ***	-8.746 ***	-15.326 ***	-15.605 ***	0.742 **	0.094

Notes: $\Delta prod_t$ is the percent change in global crude oil production, rea_t is the real economic aggregate activity index, rpo_t is the real price of oil, and ret_t is the real bond market index return. The null hypotheses for ADF and PP are: the series has a unit root I(1), whereas the null hypothesis of the KPSS test is: the series is stationary I(0). *, **, and *** denote the significant level at 1%, 5%, and 10% level respectively.

Table 1. Forecast Error Variance Decomposition (FEVD) of U.S. Aggregate Real Bond Returns

Panel A. Variance decomposition of real aggregate bond market returns

Horizon	Oil Supply Shock		Aggregate Demand Shock		Oil-Market Specific Demand Shock		Bond Market Shock	
1	0.000	0.00	0.009	(0.48)	0.004	(0.26)	0.987	(35.52)
3	0.014	(0.61)	0.028	(1.07)	0.067	(1.94)	0.892	(19.34)
12	0.069	(1.99)	0.054	(1.85)	0.070	(2.10)	0.807	(16.26)
24	0.082	(2.38)	0.093	(3.15)	0.096	(2.65)	0.728	(15.04)
60	0.084	(2.54)	0.108	(3.48)	0.114	(3.19)	0.695	(14.43)

Panel B. Spillover table when forecast horizon H=24

	Contributions From							
Contributions To	(1) Oil Supply Shock		(2) Aggregate Demand Shock		(3) Oil-Market Specific Demand Shock		(4) Bond Market Shock	
(1)	0.816	(18.00)	0.054	(2.20)	0.028	(1.29)	0.101	(2.98)
(2)	0.041	(0.63)	0.762	(6.70)	0.067	(0.90)	0.129	(1.59)
(3)	0.028	(0.49)	0.297	(2.31)	0.642	(4.88)	0.033	(0.68)
(4)	0.082	(2.38)	0.093	(3.11)	0.096	(2.69)	0.728	(15.02)

Total Spillover Index: 0.263 (6.36)

Notes: The contributions of demand and supply shocks in the crude oil market to the overall variability of real aggregate bond returns are reported as a fraction. The aggregate bond index reflects the prices of investment grade, U.S. dollar denominated, Treasury, government and corporate bonds publicly issued in the U.S. The index has an average maturity of about 5 years. The forecast error variance decomposition is based on the structural VAR model described in the text. The values in parentheses represent the absolute t-statistics when coefficients' standard errors were generated using a recursive-design wild bootstrap.

Table 2. Forecast Error Variance Decomposition (FEVD) of U.S. Corporate Real Bond Returns

Horizon	Oil Supply Shock		Aggregate Demand Shock		Oil-Market Specific Demand Shock		Other Shocks	
1	0.001	(0.06)	0.002	(0.12)	0.000	(0.00)	0.998	(45.97)
3	0.013	(0.64)	0.014	(0.68)	0.020	(0.76)	0.953	(25.79)
12	0.056	(1.75)	0.040	(1.44)	0.038	(1.33)	0.866	(18.67)
24	0.068	(2.16)	0.100	(3.12)	0.086	(2.47)	0.747	(15.29)
60	0.069	(2.29)	0.112	(3.44)	0.101	(2.96)	0.717	(14.63)

Notes: The contributions of demand and supply shocks in the crude oil market to the overall variability of real corporate bond returns are reported as a fraction. The aggregate bond index reflects the prices of investment grade corporate bonds publicly issued in the U.S. The index has an average maturity of about 5 years. The forecast error variance decomposition is based on the structural VAR model described in the text. The values in parentheses represent the absolute t-statistics when coefficients' standard errors were generated using a recursive-design wild bootstrap.

Table 3. Forecast Error Variance Decomposition (FEVD) of Government Bond Returns

Horizon	Oil Supply Shock		Aggregate Demand Shock		Oil-Market Specific Demand Shock		Other Shocks	
Panel A. 30-day government treasury bills								
1	0.010	(0.48)	0.042	(1.21)	0.186	(3.15)	0.763	(11.55)
3	0.007	(0.34)	0.065	(1.49)	0.410	(5.67)	0.518	(7.07)
12	0.038	(1.29)	0.075	(2.00)	0.390	(6.01)	0.497	(7.92)
24	0.057	(1.82)	0.085	(2.23)	0.342	(5.68)	0.516	(8.60)
60	0.078	(2.27)	0.096	(2.44)	0.312	(5.39)	0.515	(8.71)
Panel B.1-year government bonds								
1	0.001	(0.08)	0.031	(1.08)	0.053	(1.56)	0.915	(20.37)
3	0.005	(0.22)	0.045	(1.33)	0.259	(3.91)	0.692	(9.61)
12	0.036	(1.19)	0.064	(1.76)	0.249	(4.28)	0.651	(10.29)
24	0.047	(1.55)	0.070	(1.96)	0.245	(4.65)	0.638	(10.82)
60	0.053	(1.71)	0.081	(2.17)	0.244	(4.72)	0.623	(10.71)
Panel C. 5-year government bonds								
1	0.000	(0.01)	0.023	(0.87)	0.002	(0.17)	0.975	(31.84)
3	0.007	(0.36)	0.037	(1.24)	0.103	(2.61)	0.853	(16.81)
12	0.050	(1.66)	0.070	(2.05)	0.103	(2.72)	0.777	(14.89)
24	0.067	(2.12)	0.110	(3.25)	0.118	(3.26)	0.706	(14.42)
60	0.073	(2.38)	0.123	(3.58)	0.132	(3.69)	0.673	(13.91)
Panel D. 10-year government bonds								
1	0.000	(0.02)	0.008	(0.40)	0.001	(0.11)	0.990	(35.60)
3	0.012	(0.57)	0.030	(1.09)	0.069	(2.14)	0.888	(19.41)
12	0.057	(1.83)	0.063	(1.92)	0.081	(2.41)	0.799	(16.20)
24	0.075	(2.24)	0.086	(2.73)	0.096	(2.86)	0.743	(15.68)
60	0.079	(2.43)	0.100	(3.17)	0.111	(3.27)	0.711	(15.10)
Panel E. 30-year government bonds								
1	0.000	(0.01)	0.008	(0.36)	0.004	(0.27)	0.988	(33.30)
3	0.008	(0.43)	0.040	(1.23)	0.071	(2.17)	0.881	(18.02)
12	0.048	(1.60)	0.074	(2.02)	0.133	(3.14)	0.746	(13.67)
24	0.062	(2.06)	0.083	(2.43)	0.151	(3.81)	0.704	(14.00)
60	0.066	(2.26)	0.093	(2.76)	0.161	(4.15)	0.680	(14.03)

Notes: Table 3 shows percent contributions of demand and supply shocks in the crude oil market to the overall variability of real bond returns. The forecast error variance decomposition is based on the structural VAR model described in the text. The values in parentheses represent the absolute t-statistics when coefficients' standard errors were generated using a recursive-design wild bootstrap.

Table 4. Forecast Error Variance Decomposition (FEVD) of Real Aggregate Bond Returns with Expected Inflation

Panel A. Variance decomposition of real aggregate bond market returns

Horizon	Oil Supply Shock		Aggregate Demand Shock		Oil-Market Specific Demand Shock		Expected Inflation Shock		Other Shocks	
1	0.000	(0.02)	0.002	(0.12)	0.001	(0.09)	0.009	(0.50)	0.988	(32.65)
3	0.011	(0.48)	0.008	(0.43)	0.064	(1.95)	0.018	(0.82)	0.900	(20.05)
12	0.080	(2.27)	0.030	(1.29)	0.070	(2.21)	0.036	(1.46)	0.784	(15.91)
24	0.094	(2.81)	0.064	(2.51)	0.096	(2.96)	0.055	(2.20)	0.691	(14.90)
60	0.099	(3.16)	0.084	(3.16)	0.099	(3.32)	0.062	(2.61)	0.656	(14.90)

Panel B. Spillover table when forecast horizon H=24

	Contributions From									
Contributions To	(1) Oil Supply Shock		(2) Aggregate Demand Shock		(3) Oil-Market Specific Demand Shock		(4) Expected Inflation Shock		Other Shocks	
(1)	0.740	(15.30)	0.058	(2.29)	0.031	(1.36)	0.078	(2.71)	0.094	(2.98)
(2)	0.024	(0.50)	0.568	(5.16)	0.062	(1.08)	0.253	(2.54)	0.093	(1.41)
(3)	0.053	(0.86)	0.237	(2.51)	0.597	(5.89)	0.083	(1.33)	0.030	(0.67)
(4)	0.059	(0.99)	0.105	(1.25)	0.089	(1.42)	0.105	(1.63)	0.643	(5.71)
(5)	0.094	(2.79)	0.064	(2.48)	0.096	(2.95)	0.055	(2.20)	0.691	(14.93)
Total Spillover Index: 0.4598 (14.34)										

Notes: The forecast error variance decomposition is based on the structural VAR model described in the text. The values in parentheses represent the absolute t-statistics when coefficients' standard errors were generated using a recursive-design wild bootstrap.

Figure 1. U.S. Real Bond Returns, Real Price of Crude Oil, Expected Inflation, and Real Stock Return

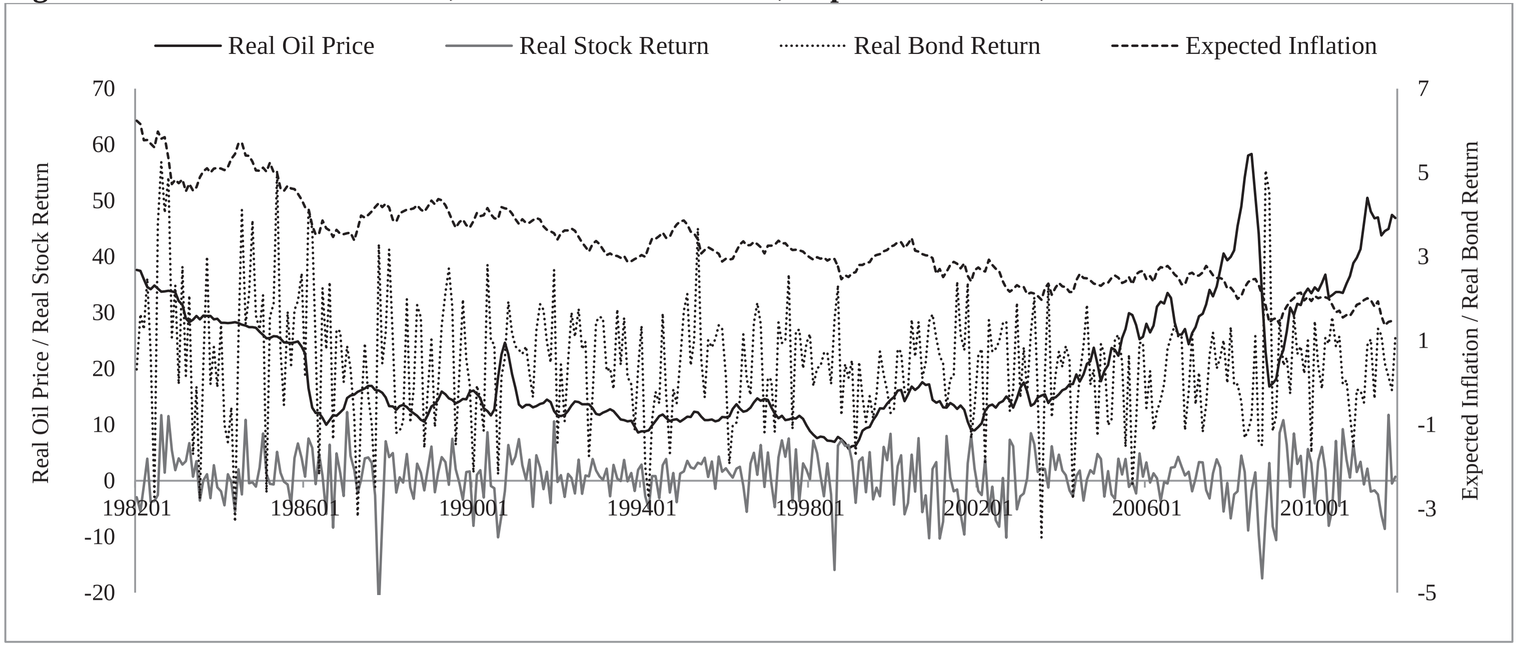
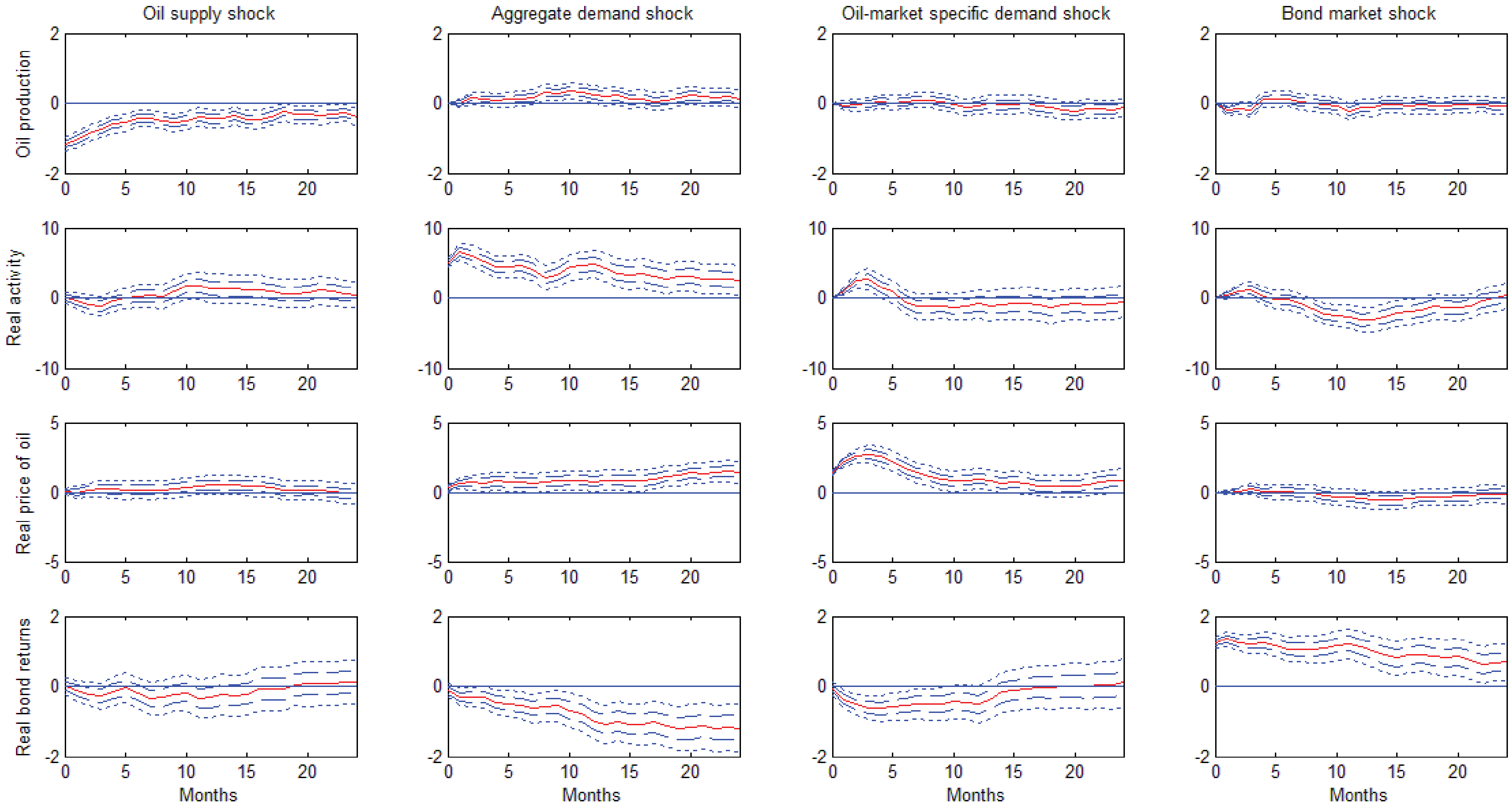


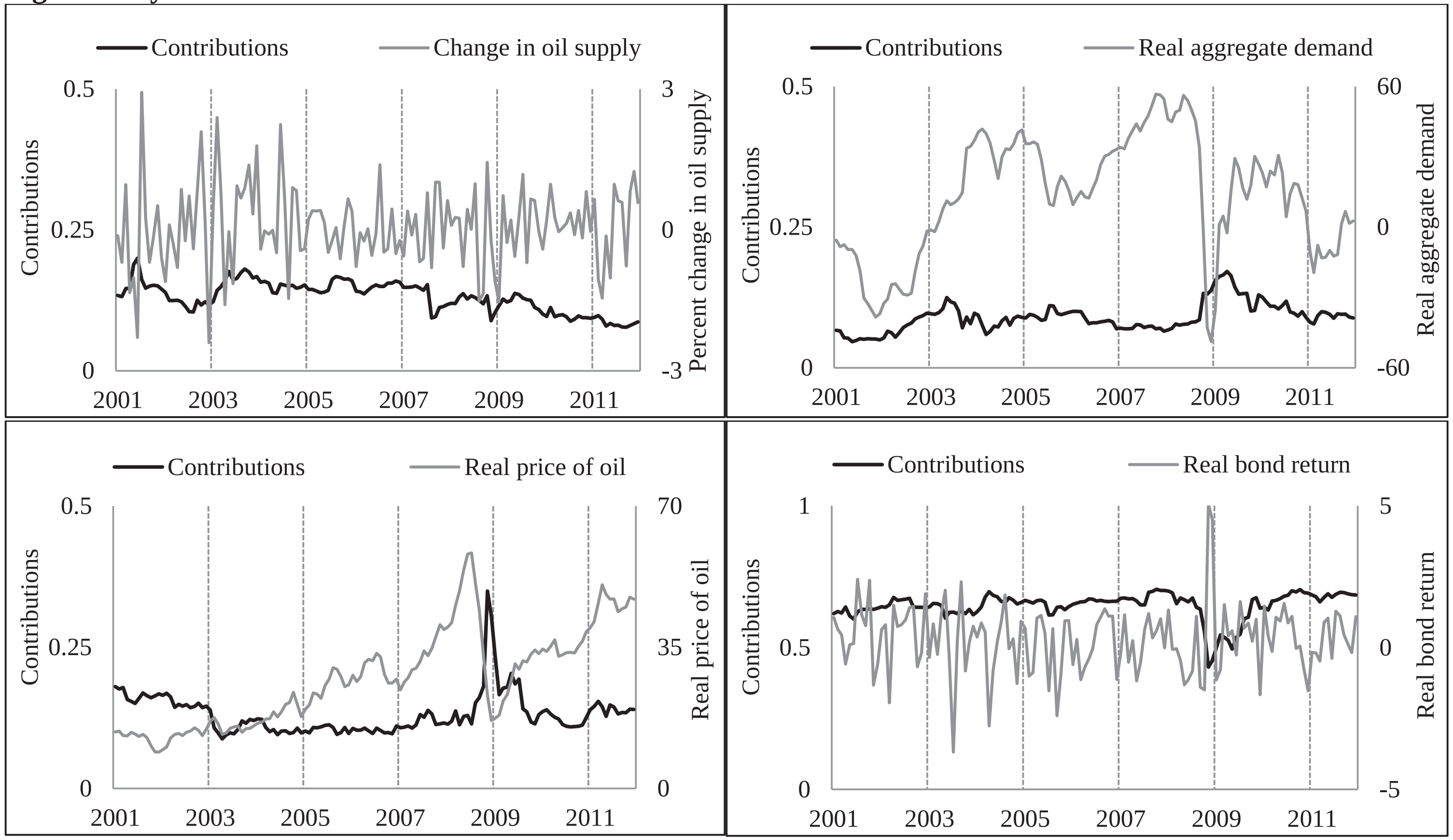
Figure 1. Real bond market returns, real price of crude oil, expected inflation, and real stock market return, 1982:1-2011:12 in United States. Notes: the expected inflation over next 5 years is from Federal Reserve Bank at Cleveland, the real price of oil is the nominal price of oil deflated by the U.S. CPI from the Bureau of Labor Statistics, and the real bond market index return and real stock market returns are from CRSP database.

Figure 2. Responses to One-Standard Deviation Structural Shocks in Oil Price Shock and U.S. Real Bond Return Variables



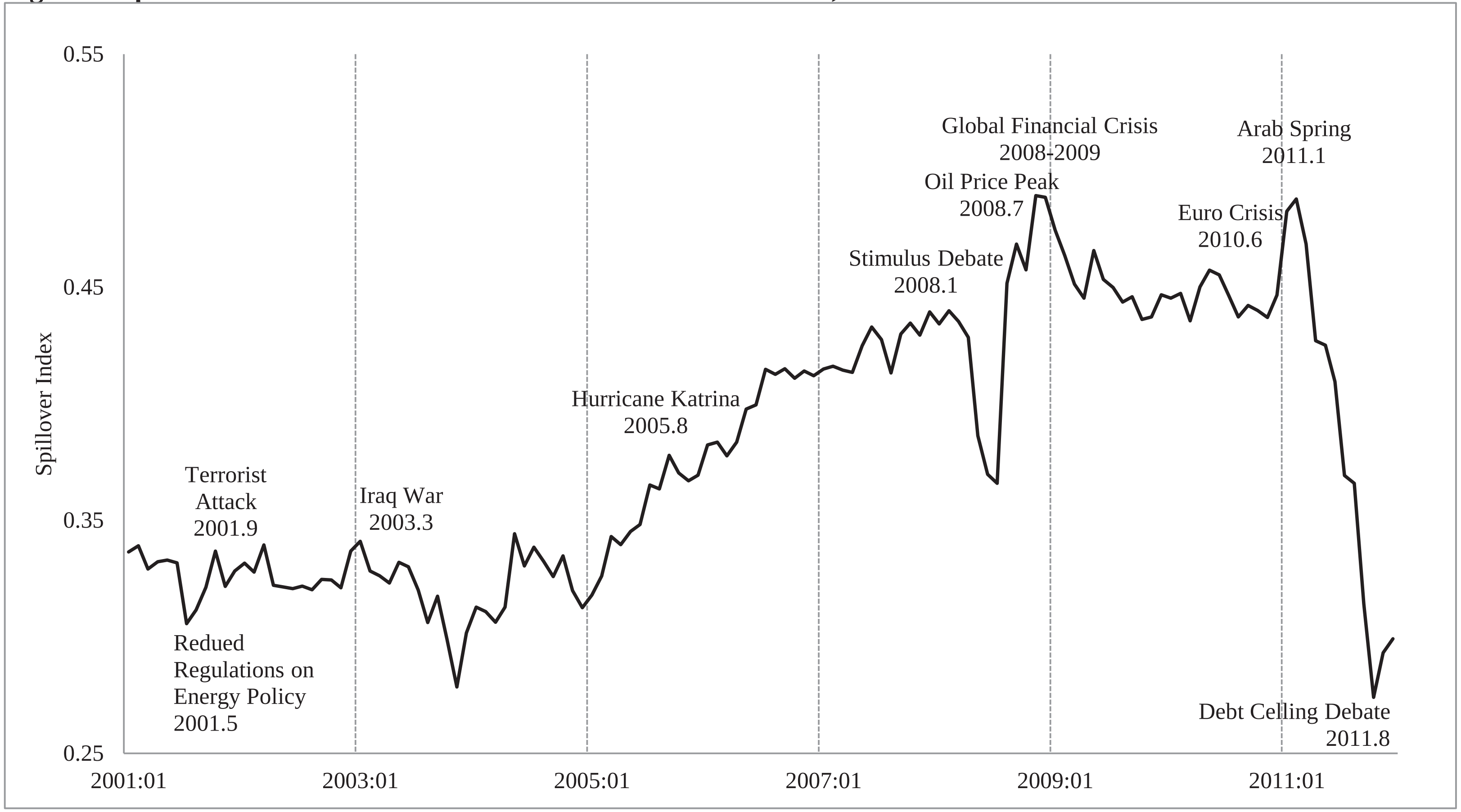
Notes: Variables are structural oil price shocks and real bond returns. The real aggregate U.S. bond market return is Barclays' capital aggregate bond index returns deflated by the U.S. CPI. Point estimates, with one- and two-standard error bands, derived from the structural VAR model described in the text. The confidence intervals were constructed using a recursive-design wild bootstrap. Impulse responses of real bond returns are cumulative.

Figure 3. Dynamic Contributions to the Variation in Real Bond Returns from Structural Oil Market Shocks: 2001:01-2011:12



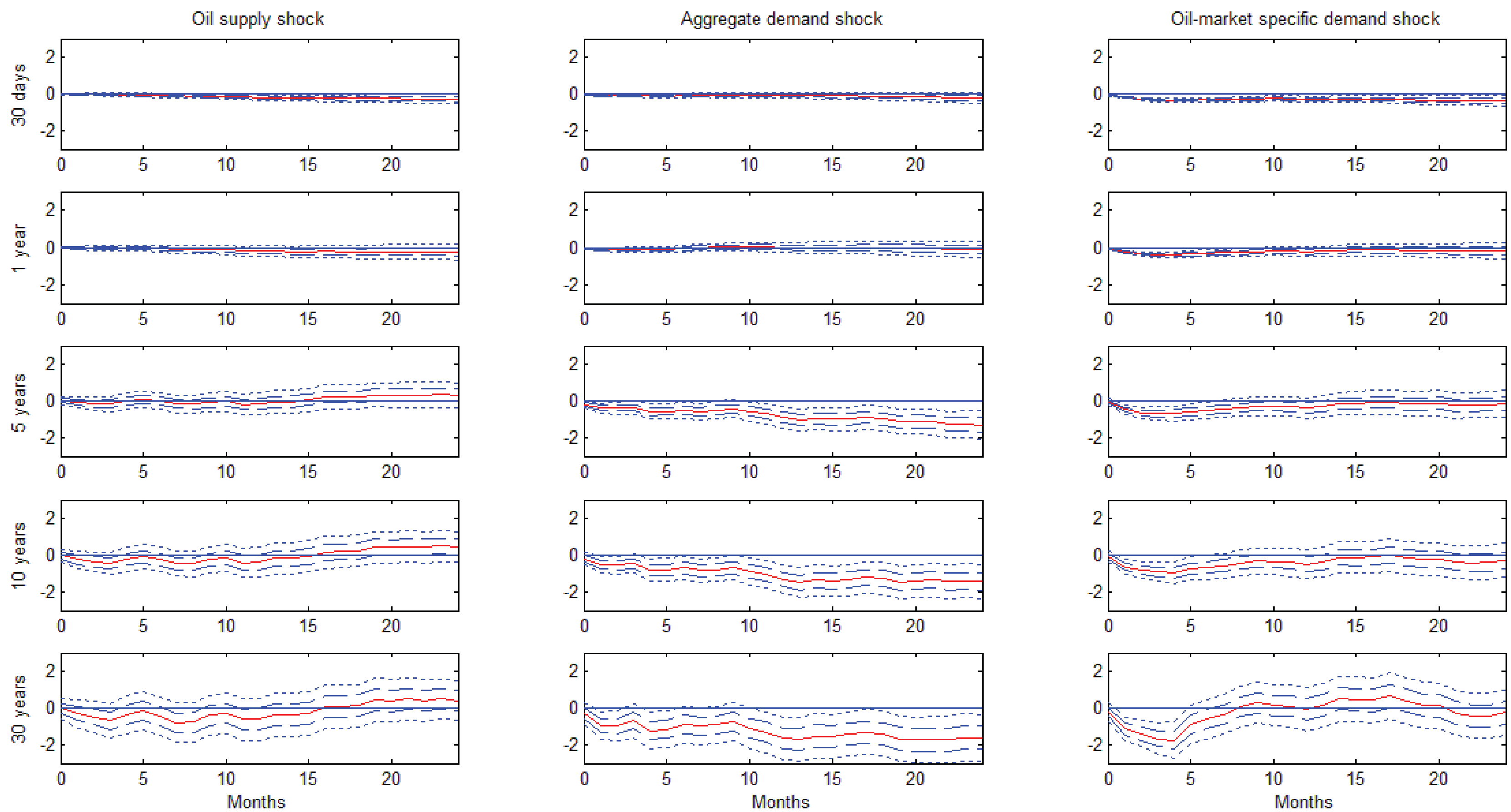
Notes: Variance decomposition contributions to the volatility of real bond returns described in the text and estimated using 228-month rolling windows.

Figure 4. Spillover Plot of Oil Shocks and Real Bond Market Returns, 2001:01-2011:12



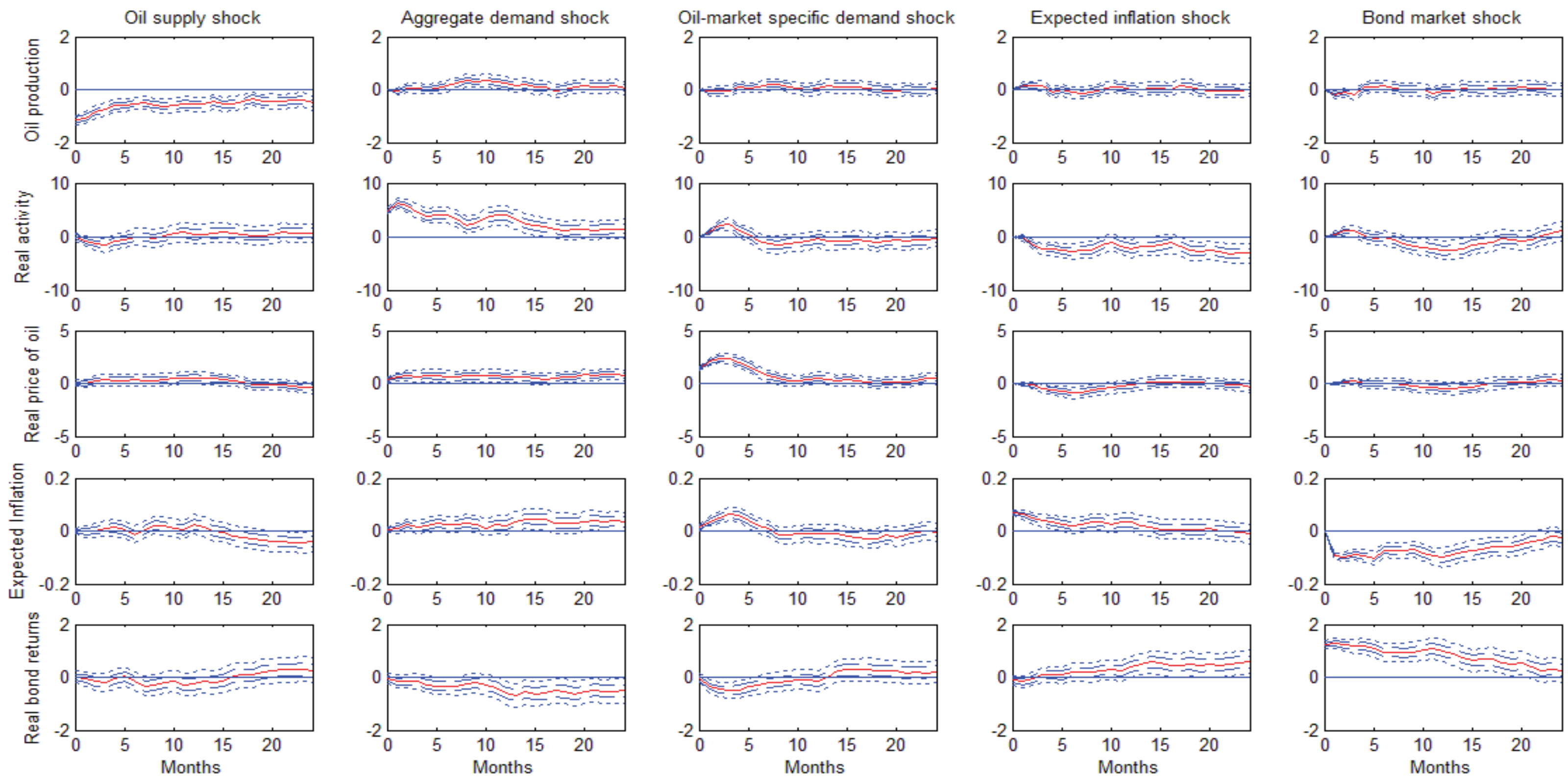
Notes: The spillover index is defined in the text as 1/4 × the sum of all variance decomposition contributions from one variable to the other variable, estimated using 228-month rolling windows.

Figure 5: Cumulative Responses in U.S. Government Real Bond Return to One-Standard Deviation Structural Oil Market Shocks



Notes: Variables are structural oil price shocks and government real bond returns. The real aggregate U.S. bond market return is Barclays' capital aggregate bond index returns deflated by the U.S. CPI. Point estimates, with one- and two-standard error bands, derived from the structural VAR model described in the text. The confidence intervals were constructed using a recursive-design wild bootstrap. Impulse responses are cumulative.

Figure 6. Responses to Structural Shocks in Oil Price Shock, Expected Inflation and Real Bond Return



Notes: Variables are structural oil price shocks, expected rate of inflation over next 5 years, and real bond returns. The aggregate bond index reflects the prices of investment grade, U.S. dollar denominated, Treasury, government and corporate bonds publicly issued in the U.S. The index has an average maturity of about 5 years. The expected rate of inflation over next 5 years is obtained from the Federal Reserve Bank of Cleveland. Point estimates, with one- and two-standard error bands, derived from the structural VAR model described in the text. The confidence intervals were constructed using a recursive-design wild bootstrap. Impulse responses of real bond returns are cumulative.

Figure 7. Cumulative Responses of Aggregate Real Bond Return with 12 lags

Figure 7.1. Cumulative Responses of Aggregate Real Bond Returns with 12 Lags

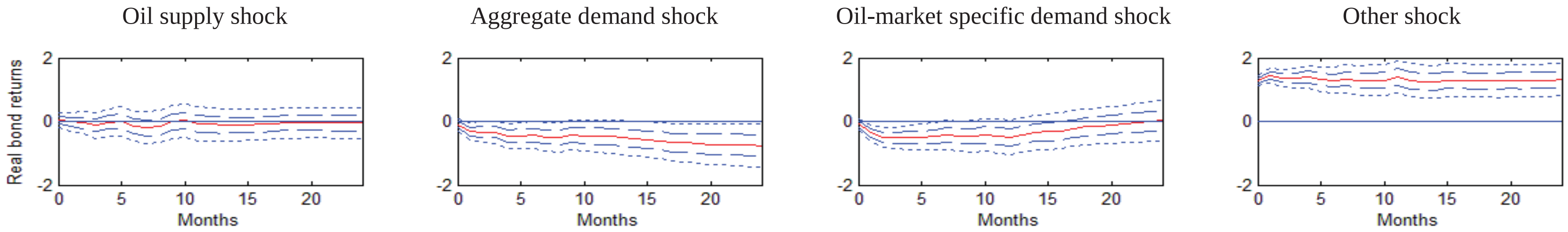
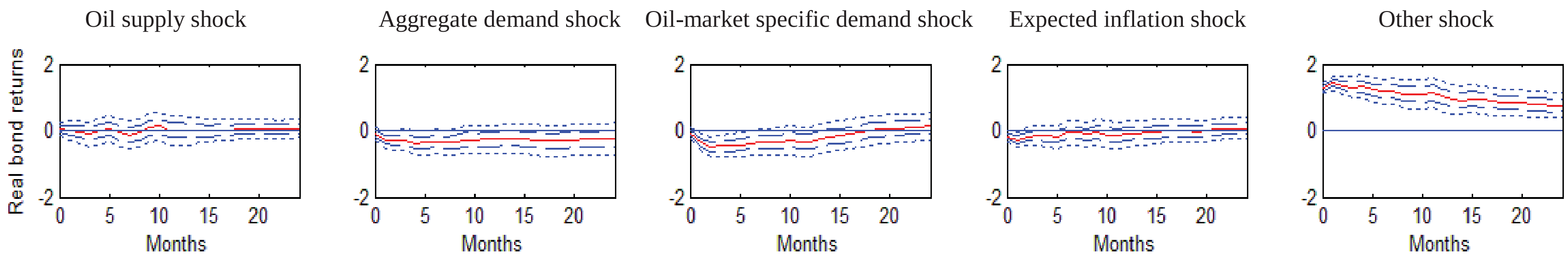


Figure 7.2. Cumulative Responses of Aggregate Real Bond Returns with Expected Inflation and 12 Lags



Notes: Variables are structural oil price shocks, expected rate of inflation over next 5 years, and real bond returns. The aggregate bond index reflects the prices of investment grade, U.S. dollar denominated, Treasury, government and corporate bonds publicly issued in the U.S. The index has an average maturity of about 5 years. The expected rate of inflation over next 5 years is obtained from the Federal Reserve Bank of Cleveland. Point estimates, with one- and two-standard error bands, derived from the structural VAR model described in the text. The confidence intervals were constructed using a recursive-design wild bootstrap. Impulse responses of real bond returns are cumulative.