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Oil Price Shocks and the Credit Default Swap Market

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Abstract We investigate the impact of supply and demand shocks in the global crude oil market on the CDX spread, in the context of a structural VAR model based on monthly data, over the period from November 2003 to October 2015. We find that the reaction of the CDX spread to changes in the real price of crude oil differs considerably depending on the sources of shocks. In the long run, crude oil supply shocks, aggregate demand shocks, and oil-specific demand shocks together account for nearly 90% of the variation of the CDX spread.

1 Introduction

Credit default swaps (CDSs) have drawn many observers' attention since the start of the 2007–2009 financial crisis. For example, Fostel and Geanakoplos (2012, 2016) argue that the creation of CDSs caused the collapse of estate prices during the crisis. Stulz (2010) reviews the role CDSs played in the financial market and argues that CDSs (and other financial derivatives) were not the primary factors that led to the financial crisis. Chen and Härdle (2015) examine the common factors driving the CDS spread fluctuations during the pre-crisis, crisis, and post-crisis period. Norden and Weber (2009) shed light on the co-movements of the CDS, bond, and stock markets. Arora *et al.* (2011) show how to price credit risk through the use of CDS market data.

However, there are few studies that focus on the interactions between the CDS market and commodity markets. In particular, albeit crude oil price changes are considered to be a factor affecting economic growth and stock market performance, no study has investigated the relationship between the crude oil market and the CDS market. In this paper, we fill that gap and try to answer two questions: Do crude oil

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price shocks affect CDS indices? Do the shocks from different sources in the crude oil market have different effects on CDS indices?

A CDS is a financial agreement in which the buyer purchases insurance against a contingent credit event on an underlying reference entity by paying an annuity premium to the seller, which is called "spread," over the life of the contract. In other words, it is similar to insurance as it provides the buyer protection against loan default or other credit events. The spread paid by the buyer is similar to an insurance premium. The seller has to compensate the buyer only if a negative credit event occurs (loan default, credit rating downgrade, bankruptcy, etc.).

A CDS contract is not tied to a bond; instead, it just references it. The buyer of a CDS does not need to hold the reference entity. Thus, the buyer can earn a profit when the reference entity has a negative credit event if the buyer does not actually hold the reference entity. On the other side, the seller receives periodic fees (spreads) from the buyer and makes a profit if the reference entity has no negative credit events over the life of the contract. However, the seller takes the risk of big losses if the reference entity has a negative credit event.

The spread of a CDS is the amount that the buyer has to pay the seller annually over the life of the contract. It is usually expressed as a percentage of the notional amount, and the basic unit is the basis point (bp, 1 bp = 0.01%). For example, if the CDS spread of a bond is 100 bps (1%), then one buying $1 million worth of protection should pay the seller $10,000 annually. The spread will be higher if the probability that the reference entity will have a negative credit event is larger. In other words, a higher spread means a higher risk of a negative credit event. Thus, a given CDS contract with a predetermined spread is worth more for the buyer and less for the seller if the probability that a negative credit event will occur increases.

CDSs were invented in 1994, and they have been used largely since 2003. Fig. 1 shows that the CDS notional amount surged over the period from 2005 to 2008. By the end of 2007, the CDS notional amount peaked at more than $58 trillion U.S. dollars, followed by a dramatic decline in the following two years. Although it had a small recovery in 2011, the CDS notional amount fell 80% to about $12 trillion by the end of 2015.[1]

To the best of our knowledge, few studies, either theoretical or empirical, have directly investigated the relationship between the CDS market and the crude oil market (or any other commodity markets). The relationship between oil prices and other financial markets, especially the stock market, has been extensively investigated. However, there is no consensus about this relationship among economists. Most of the literature focuses on the interactions between oil prices and the stock market. For example, Chen *et al*. (1986) claims that oil price changes have no effect on stock prices. In contrast, Jones and Kaul (1996) find that oil price hikes have a statistically significant negative effect on stock markets in the United States, Canada, Japan, and the United Kingdom. But Huang *et al*. (1996) argue that oil futures returns are not correlated with stock market returns during the 1980s.

Recently, Park and Ratti (2008) find that oil price innovations have a statistically significant impact on real stock returns instantaneously and within one month

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[1] Data source: Bank for International Settlements (BIS), http://www.bis.org/statistics/derstats.htm.
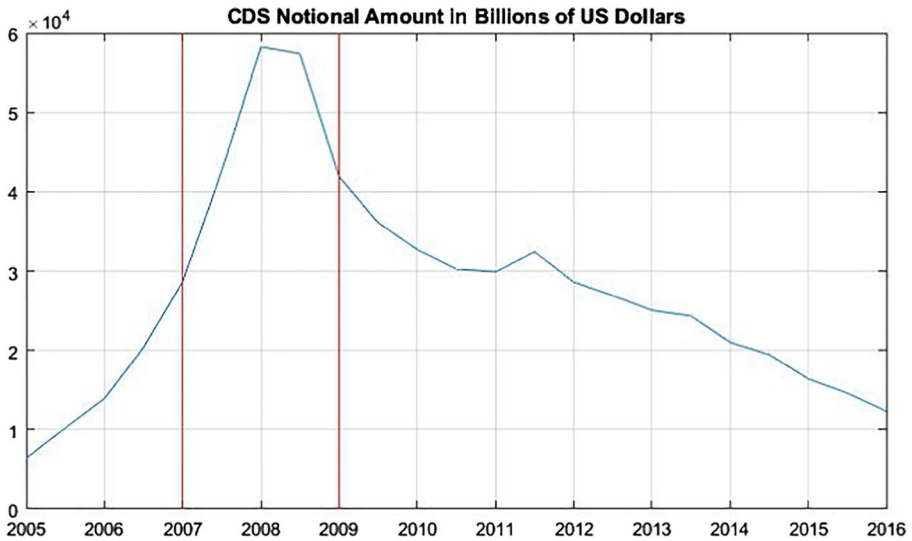
Fig. 1 CDS notional amount in billions of U.S. dollars, 2005–2016

by employing a vector autoregression (VAR) model with data from the United States and thirteen European countries from 1986 to 2005. Kilian and Park (2009) examine the responses of stock returns to structural shocks in the oil market leading to oil price variations. They find that the responses vary depending on the sources of price changes.

However, we can hardly rely on previous research to improve our understanding of the interaction between the crude oil market and the CDS market. First, stocks and CDSs are two different types of financial products. The stock represents shares of a corporation, which is a fraction of ownership. The CDS is a financial derivative based on a company's bonds and provides protection against loan default (or other credit events). Thus, it is necessary to explicitly study the relationship between the CDS market and the crude oil market.

In this paper, inspired by Kilian and Park (2009) who investigate the relation-ship between the crude oil market and the U.S. stock market, and Jadidzadeh and Serletis (2016) who investigate the relationship between the crude oil market and the U.S. natural gas market using the Kilian and Park (2009) methodology, we build a structural VAR model augmented with the CDX spread to investigate the relationship between the crude oil market and the CDS market. Following Kilian (2009), we treat the crude oil price as endogenous, and distinguish between three sources of changes in crude oil prices: shocks to crude oil supply, shocks to the demand for all industrial commodities, and shocks to the specific demand (precau-tionary demand) for crude oil. We use monthly data, over the period from November 2003 to October 2015, and find that oil supply shocks, aggregate demand shocks, and oil-specific demand shocks generate different responses of the CDX spread. In the long run, these shocks account for about 90% of the variation in the CDX spread.

The rest of the paper is organized as follows. In Section II we discuss the data, in Section III the methodology, and in Section IV we present the empirical results. The last section briefly concludes the paper.

2 Data

Our monthly data include the percentage change in world crude oil production, $\Delta prod_t$, an indicator of global real economic activity, rea_t, the real price of crude oil imported by the United States, rpo_t, and the CDX spread, cdx_t. The sample period is November 2003 to October 2015.

The percentage change in world crude oil production ($\Delta prod_t$) is constructed based on the production data (crude oil and lease condensate) from the U.S. Energy Information Administration (EIA).[2] We compute the log differences of monthly world crude oil production data in thousands of barrels pumped per day (ppl/d), averaged by month.

To measure the level of global real economic activity driving the aggregate demand for all industrial commodities, Kilian (2009) constructed an index, rea_t, by using of representative single-voyage freight rates. He eliminated the fixed effects in constructing this series and deflated it with the U.S. Consumer Price Index (CPI) from the Bureau of Labor Statistics. To remove the long-run trends related to technological advances and demand for sea transport, this real index is linearly detrended so it represents the global business cycle.[3]

The measure of the real price of crude oil imported by the United States (rpo_t) is constructed by deflating the U.S. refiner acquisition cost of crude oil from EIA with the U.S. CPI. This series is expressed in logs.

Instead of single-name reference entity CDS contracts, we focus on CDS index series in this paper. The Markit CDX is a family of tradable CDS indices covering North America and emerging markets. They are completely standardized securities and traded in spreads. In comparison to single-name CDS contracts, there are several benefits to be gained by using CDS indices. In particular, index trading is more efficient and provides more liquidity. In addition, CDX indices are accepted as key benchmarks of credit risk, and their data can be obtained daily. The Markit CDX North American Investment Grade (CDX.NA.IG) is the most common index. It consists of 125 mostly liquid investment-grade CDSs on U.S. firms that are equally weighted. The CDX indices roll out every six months, in March and September. The first series was issued in October 2003. We obtain the CDX data from Bloomberg for the sample period from November 2003 to October 2015.

We obtain the monthly time series of CDX spreads and compute logs based on the Markit CDX.NA.IG Series 1 to Series 25 over the sample period from Bloomberg. The historical evolution of the series over the sample period is presented in Fig. 2; vertical red lines indicate the period of the global financial crisis.

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[2] Source: U.S. EIA Beta website, http://www.eia.gov/beta/international/.
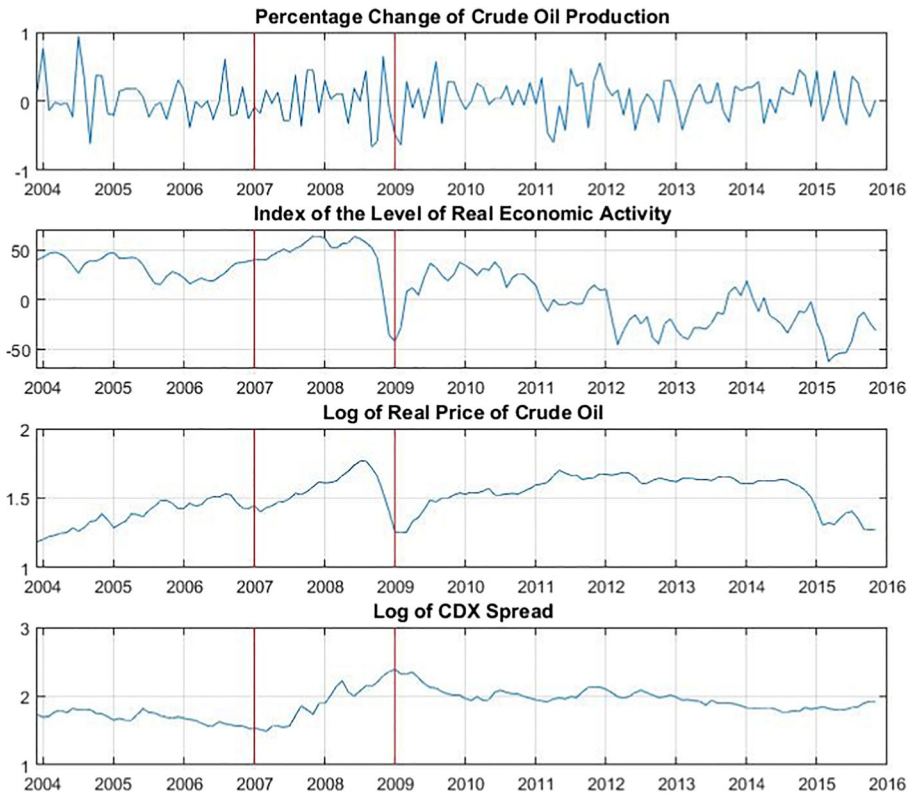[3] See more discussion on the construction of this index in Kilian and Park (2009).

Fig. 2 Historical evolution of the series, November 2003 to October 2015

As can be seen, the levels of global real economic activity and real price of crude oil dramatically fell in the second half of 2008. During the same period, the CDX spread surged and reached a peak at the end of 2008.

3 Methodology

The structural representation of the VAR model in this model is

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \varepsilon_t \tag{1}$$

where $z_t = (\Delta prod_t, rea_t, rpo_t, cdx_t)'$ and ε_t denotes the vector of serially and mutually uncorrelated structural innovations. The reduced-form representation of eq. (1) is

$$z_t = \gamma + \sum_{i=1}^{24} B_i z_{t-i} + e_t \tag{2}$$

where $B_i = A_0^{-1} A_i$ and $e_t = A_0^{-1} \varepsilon_t$. The structural shocks ε_t and the structural parameters can be recovered by using the reduced-form estimation after imposing exclusion restrictions on A_0^{-1}.

As suggested by Kilian and Park (2009), A_0^{-1} has a block-recursive structure as follows

$$A_0^{-1} = \begin{pmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \tag{3}$$

so the reduced-form innovations e_t can be decomposed as

$$e_t \equiv \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \\ e_t^{cdx} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil\ supply\ shock} \\ \varepsilon_t^{aggregate\ demand\ shock} \\ \varepsilon_t^{oil\ specific-demand\ shock} \\ \varepsilon_t^{other\ shocks\ to\ CDX\ spreads} \end{pmatrix}. \tag{4}$$

The first block, which is composed of the first three equations in (4), constitutes a model of the world crude oil market. The second block consists of the CDX spreads, which only includes the last equation.

Structural Shocks Following Kilian (2009), we attribute the real price of crude oil fluctuations in the world crude oil market block to three structural shocks: (1) shocks to the global crude oil supply, which capture the unpredictable changes in global oil production (hereafter, "oil supply shocks"); (2) shocks to the demand for all industrial commodities, including crude oil (hereafter, "aggregate demand shocks"), which are driven by the business cycle and relate to the level of global economic activity; and (3) shocks to the specific demand (or precautionary demand) for crude oil (hereafter, "oil-specific demand shocks"). These shocks capture the fluctuations in the real price of crude oil, which cannot be explained by the oil supply shocks and aggregate demand shocks. Alquist and Kilian (2010) argue that the precautionary demand for crude oil arises from the uncertainty about future oil supply shortfalls and will cause an immediate increase in the real spot price of crude oil.[4] Therefore, oil-specific demand shocks can reflect the changes in the real price of crude oil caused by precautionary needs that are not captured by supply shocks and aggregate demand shocks.

The CDX spreads block only contains the last equation in (4). This structural shock can be treated as an innovation to the CDX spreads which is not driven by crude oil supply or demand shocks. In other words, it is not a true structural shock but captures the fluctuations in the CDX spreads caused by other shocks, except the ones in the world crude oil market. We do not attempt to distinguish between the different factors driving this shock, because this paper focuses on the responses of CDX spreads to shocks in the crude oil market.

Identification Assumptions The exclusion restrictions imposed on A_0^{-1} in the first block imply that the supply of crude oil does not contemporaneously respond to changes in the demand for crude oil. This is consistent with a crude oil market model consisting of a vertical short-run supply curve and a downward-sloping demand curve.

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[4] See more discussion on the precautionary demand for crude oil in Alquist and Kilian (2010).

The first row of A_0^{-1}, in which $a_{12} = a_{13} = a_{14} = 0$, implies that shocks to aggregate demand for industrial commodities and precautionary demand for crude oil, and other shocks to the CDX spreads, do not affect the supply of crude oil contemporaneously, but affect it with a delay of at least one month. It is consistent with the notion that given the costs of changing production plans, producers need time to adjust supply. In the second row of A_0^{-1}, the restriction $a_{23} = a_{24} = 0$ implies that shocks to crude oil production and aggregate demand for industrial commodities have contemporaneous effects on the level of global economic activity. The restriction $a_{34} = 0$ in the third equation of the first block implies that the real price of crude oil reacts to other shocks to CDX spreads with a lag. It contemporaneously responds to unpredictable shocks to crude oil supply, which shifts the vertical short-run oil supply curve. It also reacts to aggregate demand for industrial commodities and precautionary demand for crude oil within a month, each of which drives the shift of the downward-sloping demand curve.

The second block only contains the last equation. The forth row of A_0^{-1}, in which all elements are nonzero, implies that the world crude oil production, global real economic activity, and the real price of crude oil are treated as predetermined with respect to the CDX spreads. In other words, world crude oil production, global economic activity, and precautionary demand for crude oil contemporaneously affect CDX spreads.

4 Empirical Results

The reduced-form VAR model (2) is estimated using the least-squares method, and we use the resulting estimates to recover the structural VAR representation of the model. Finally, we compute the impulse response functions to one-standard-error shocks following the recursive-design wild bootstrap with 2000 replications in Gonçalves and Kilian (2004).

4.1 The Effects of Crude Oil Supply and Demand Shocks on the Real Price of Crude Oil

We first present the impulse responses and cumulative impulse responses of the real price of crude oil to supply and demand structural shocks in the oil market in Fig. 3 and Fig. 4, respectively. The supply innovation is normalized to a negative shock (which shifts the vertical short-run supply curve leftward), and the aggregate demand and precautionary demand innovations are normalized to positive shocks (which shifts the downward-sloping demand curve rightward), so all three shocks tend to raise the real price of crude oil. In the figures that follow, solid lines indicate the point estimates, and dashed and dotted lines represent one-standard-error and two-standard-error bands, respectively.

Figures 3 and 4 show that the three structural shocks have different effects on the real price of crude oil. An unexpected oil supply shock only produces a small, statistically insignificant positive impact on the real oil price after ten months, which is illustrated in the left graph of Fig. 3. This impact is not statistically distinguishable from zero based on both one- and two-standard error bands (see the left graph of Fig. 4). As is shown in the middle graph of Fig. 3, an unexpected positive aggregate demand shock for industrial commodities has a transitory, positive effect on the real price of oil; this effect disappears
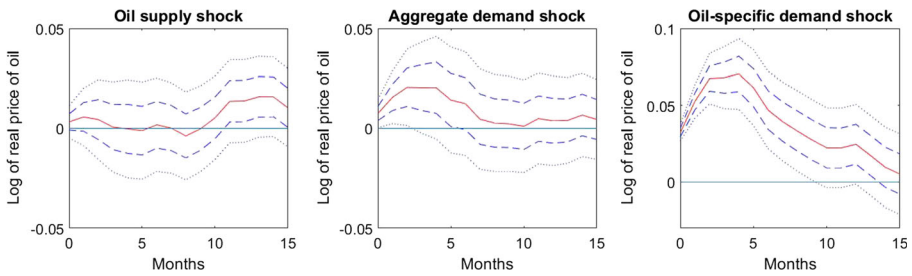
Fig. 3 Responses of the real price of crude oil to three structural shocks

after six months. The middle graph of Fig. 4 shows that the cumulative response steadily increases within the first five months and then reaches a plateau over the next ten months. Finally, an unexpected precautionary demand expansion causes an immediate, persistent, and statistically significant increase in the real price of crude oil, followed by a gradual decline (see the right graph of Fig. 3). The cumulative response of the real price of oil keeps increasing over the period (see the right graph of Fig. 4).

In Fig. 5, we present the historical decomposition of fluctuations in the real price of crude oil. As can be seen, from 2007 to late 2015 the fluctuations in the real price of crude oil were mainly driven by oil-specific demand (precautionary demand) and aggregate demand shocks, rather than crude oil production disruptions.

For example, the dramatic decline of the oil price in 2008 was driven by a combination of aggregate demand shocks and precautionary shocks, and the recent collapse of the oil price in 2014 was almost entirely driven by oil-specific demand shocks.

4.2 Responses and Variance Decomposition of the CDX Spread

Figure 6 shows the cumulative impulse responses of the CDX spread to each of three one-standard-deviation structural innovations in the crude oil market.

We find that although all three shocks lead to an increase in the real price of crude oil, the responses of the CDX spread vary substantially, depending on the underlying causes. In the left graph, an unexpected oil supply shock causes a slight increase in the CDX spread after five months. The effect is persistent and lasts about ten months, although it is insignificant in some months based on one- and two-standard-error bands. The second graph illustrates that an aggregate demand
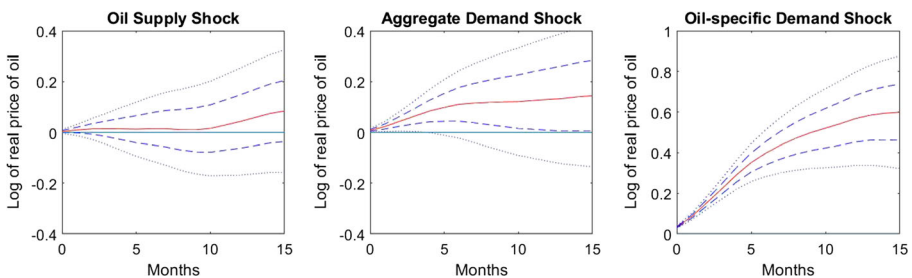

Fig. 4 Cumulative responses of the real price of crude oil to three structural shocks
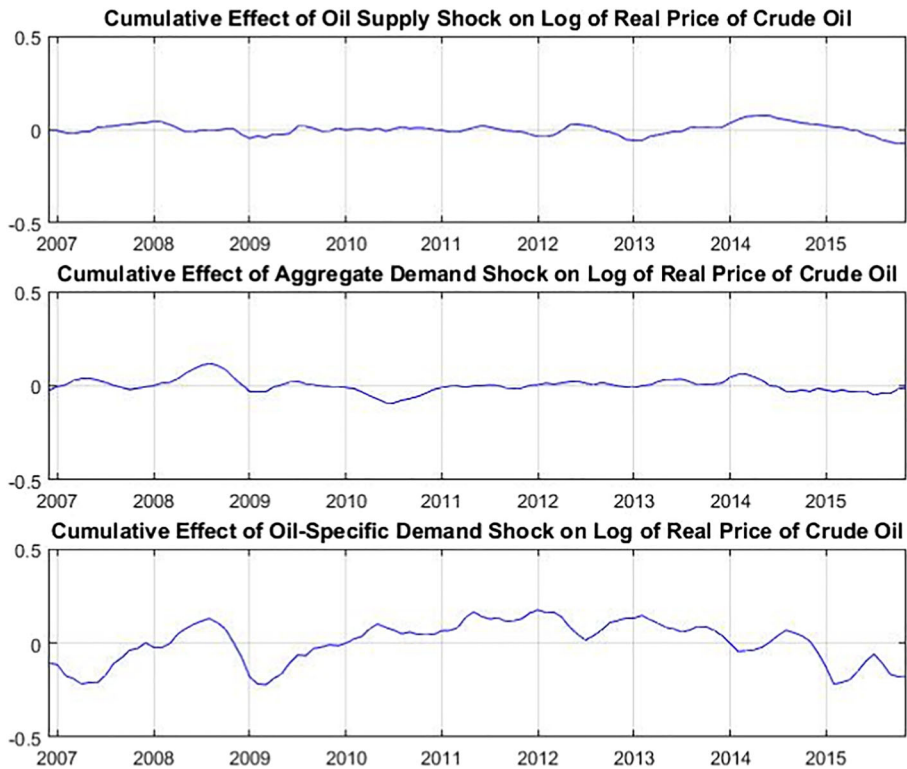
Fig. 5 Historical decomposition of the real price of crude oil

expansion causes a sustained decline in the CDX spread upon impact. The CDX spread gradually falls within ten months, followed by a very slight recovery. This shock has a statistically significant, negative effect on the CDX spread based on one-standard-error bands. As is shown in the right graph, a positive unexpected oil-specific demand shock has a large and persistent negative effect on the CDX spread that is highly statistically significant based on both one- and two-standard-error bands.

The variance decomposition in Table 1 quantifies how important the structural innovations are on average for the CDX spread. In the short run, about half of the
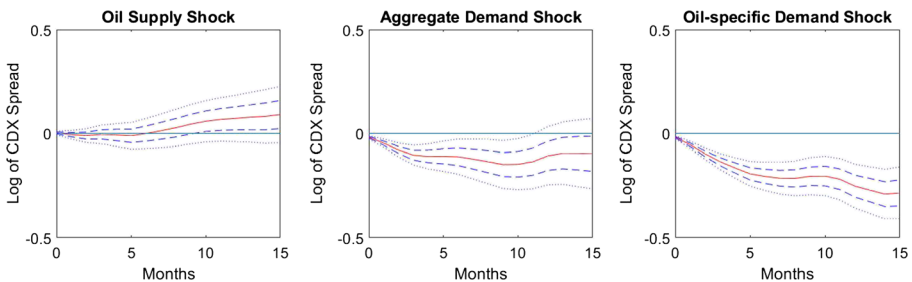

Fig. 6 Responses of the CDX spread to three structural shocks

Table 1 Percent contribution of demand and supply shocks in the crude oil market to the overall variability of the CDX spread

Horizon	Oil supply shock	Aggregate demand shock	Oil-specific demand shock	Other shocks
1	0.23	18.56	19.05	62.16
2	1.54	22.71	32.42	43.33
3	1.15	26.52	41.94	30.38
12	7.33	20.82	42.81	29.04
∞	33.28	12.5	42.89	11.33

variation can be attributed to supply and demand shocks in the crude oil market. The explanatory power increases as the horizon is lengthened. In the long run, nearly 90% of the variation of the CDX spread is accounted for by the oil supply shocks, aggregate demand shocks, and precautionary demand shocks. This suggests that structural shocks in the oil market are an important fundamental for the CDX spread.

4.3 Implications of the Impulse Response Analysis

In general, the CDX spread can be treated as an indicator of the credit risk level of the North American market. The shocks in the crude oil market can influence economic performance as well as credit risk. The reaction of the CDX spread to the shocks in the crude oil market reflects the changes in credit risk. We find that a crude oil production disruption will cause credit risk to increase. An expansion of the aggregate demand for industrial commodities or the precautionary demand for crude oil lowers credit risk.

These results are consistent with some fundamental features of the interaction between the global crude oil market and economic performance. For example, economic performance in the United States is threatened by unexpected crude oil production cuts caused by conflicts in the Middle East (e.g. the Iran–Iraq War, the Gulf War, the Israeli-Palestinian conflict, and the Jasmine Revolution), thereby increasing credit risk. On the other hand, an aggregate demand expansion is usually accompanied by improvements in manufacturing, which lower the overall level of credit risk. The precautionary demand for oil arises from the uncertainty about future oil price fluctuations. An increase in the precautionary demand helps reduce credit risk associated with future unexpected shortfalls of oil supply.

Although the channels through which supply and demand shocks in the global crude oil market affect the CDX spread are not clear, the evidence shows that it will be misleading to just link oil price changes to the CDX spread and credit risk levels without identifying the underlying sources. Our results show that although all three shocks tend to increase the real price of crude oil, they generate different response of the CDX spread and credit risk. One surprising result is that in the long run, supply and demand shocks in the global crude oil market explain about 90% of the variation of the CDX spread; in comparison, Kilian and Park (2009) report that such shocks explain about 22% of the variation of U.S. real stock returns. At this stage, as the specific channels through which oil market shocks affect the CDS market are not clear, we cannot provide an explanation as to why the CDS market reacts more than the stock market to supply and demand shocks in the global crude oil market. We leave this as an area for potentially productive future research.

5 Conclusion

By using a structural VAR model, we investigate the responses of the CDX spread to supply and demand shocks in the global crude oil market. Over the sample period, from November 2003 to October 2015, our results show that the response of the CDX spread depends on the sources of shocks in the real price of crude oil. In addition, about 90% of the variation in the CDX spread can be attributed to structural shocks in the crude oil market. Our analysis has direct implications for the construction of dynamic stochastic general equilibrium models relating the CDS market to the crude oil market.

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