Do Financial Investors Destabilize the Oil Price?

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Abstract

We assess whether and to what extent financial activity in the oil futures markets has contributed to destabilize oil prices in recent years. We define a destabilizing financial shock as a shift in oil prices that is not related to current and expected fundamentals, and thereby distorts efficient pricing in the oil market. Using a structural VAR model identified with sign restrictions, we disentangle this non-fundamental financial shock from fundamental shocks to oil supply and demand to determine their relative importance. We find that shocks to oil demand and supply remain the main drivers of oil price swings. Financial investors in the futures market can however destabilize oil spot prices, although only in the short run. Moreover, financial activity appears to have exacerbated gyrations in the oil market over the past decade, particularly in 2007-2009.

Keywords: Oil price, Speculation, Structural VAR, Sign restrictions.

JEL Classification : C32, Q41, G13, G18

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1 Introduction

The massive oil price fluctuations observed in the last few years led many commentators to reexamine the functioning of the price-setting mechanism in the oil market (Khan 2009, Kaufmann and Ullman 2009, Miller and Ratti 2009).[1] The increasing financialization of the oil futures markets was blamed by some as the main driver of the escalation of oil prices, in addition to the more conventional explanations of surging demand and tight oil supply. It is indeed true that the oil futures market has become increasingly liquid, and the activity of agents that do not deal with physical oil, the so-called 'non-commercials', has greatly increased. Furthermore, passive index funds, whose goal is to provide investors with long-only exposure to oil, have witnessed substantial inflows in recent years (CFTC 2008). This led some to hypothesize that such inflows in the futures market may have pushed oil prices above the level warranted by the fundamental forces of supply and demand.

This paper evaluates the relative importance of financial activity in determining the spot price of oil. Using a sign-restricted structural VAR model which is estimated on global oil market data over the last two decades, we disentangle the influence of a financial shock that affects pricing in the oil market. We quantify its contribution in generating fluctuations in the oil price, relative to oil supply and demand shocks conventionally studied in the literature. The novel contribution of this paper is that we focus on a financial shock to the futures price which is not linked to current and expected fundamentals. The identification restrictions employed to single out this shock are derived from a simple theoretical model that links the spot price of oil to the futures price through a no-arbitrage condition. The financial shock drives a wedge in the no-arbitrage condition, and hence drifts the oil price away from the level justified by market fundamentals. For this reason, we label the structural disturbance as a destabilizing financial shock.

Elaborating upon the work of Peersman and Van Robays (2009, 2012) and Kilian and Murphy (2010) by explicitly including the futures market in a sign-restricted VAR, we identify four different types of oil shocks: an oil supply shock, an oil demand shock driven by economic activity, an oil-specific demand shock which captures changes in oil

[1] After having surged with increasing momentum to an unprecedented level of USD 120 per barrel in the summer of 2008, oil prices fell abruptly to reach USD 45 per barrel at the end of 2008 in the wake of the financial crisis and the subsequent global economic downturn. Oil prices started rebounding in the second quarter of 2009 and experienced a strong upturn rising since then.

demand other than those caused by economic activity, and a destabilizing financial shock. We argue that it is necessary to include the oil futures market in the analysis to properly identify financial speculation shocks, in contrast to relying on complete arbitrage as Kilian and Murphy (2010) for example.

Our results suggest that financial activity in the futures market can significantly affect oil prices in the spot market, although only in the short run. In contrast, fundamental shocks to oil supply and demand cause oil prices to shift permanently. Over different forecast horizons, the destabilizing financial shock only explains about 10 percent of the total variability in oil prices, as shocks to fundamentals account for about 90 percent of the short-run forecast error variance decomposition over our sample. Moreover, we find that financial investors did cause oil prices to diverge substantially from the level justified by oil supply and demand at specific points in time over the past decade, particularly in 2007-2009. However, innovations to fundamentals still account for most of the recent oil price fluctuations. The gradual run-up in oil prices between 2002 and the summer of 2008 was mainly driven by a series of stronger-than-expected oil demand shocks on the back of booming economic activity, in combination with an increasingly tight oil supply from mid 2004 on. Strong demand-side growth together with stagnating supply are also the main driving factors behind the surge in oil prices between 2007 and mid 2008, consistent with the results in the literature (e.g. Hamilton 2009, Kilian 2009 and related papers). Nevertheless, financial activity caused oil prices to substantially overshoot their fundamental level in the first half of 2008. This is also true for the second half of 2008, in which oil prices dropped considerably in the wake of the financial crisis and the subsequent global economic downturn. Finally, we find that rising oil demand on the back of a recovering global economy drove most of the recent recovery in oil prices since the beginning of 2009.

This paper relates to different strands of the oil literature. First, several studies have analyzed the effect of speculation on the oil spot price, mostly using data on trader's positions in the futures market (IMF 2006, Haigh et al. 2007, Büyüksahin et al. 2008). Mostly, they find no significant role of financial activity. However, the distinction made between speculative activity (i.e. non-commercial trading) and non-speculative activity (i.e. commercial trading or hedging) may be arbitrary in some cases, and the publicly available data on speculative trading activity is not completely representative of all sorts of financial activity in these futures markets.[2] For example, index funds only enter on the long side of the crude oil futures market to hedge. Although the activity of index funds is typically not regarded as speculation as they follow a passive investment strategy, they may distort price formation by creating additional demand for futures contracts. This type of financial activity is not accounted for when using non-commercial trading data to assess the impact of speculative trading on the oil price. Studies aimed at evaluating the role of the index funds directly using trader's position data, on the other hand, also have to rely on rough approximations.[3] For this reason, we assess the impact of financial activity on oil spot prices without relying on trader position data. Moreover, we only evaluate the impact of financial activity that effectively distorts price formation in the physical oil market, and thereby creates deviations in the oil price from the level justified by oil demand and supply-side fundamentals.

A second strand of related literature examines the effect of changing oil demand and supply-side fundamentals on the oil price. Most of the policy and academic literature still ascribes recent oil price fluctuations to changes in fundamentals. The oil price rise over the period 2003-2008 is mainly attributed to strong oil demand confronting stagnating global oil production (Hamilton 2009, Kilian 2009, Kilian 2010, Kilian and Murphy 2010). Baumeister and Peersman (2008, 2010) observe that the price elasticities of oil demand and supply have become much smaller over time, leading to increased oil price sensitivity to similar changes in fundamentals. Anzuini, Lombardi and Pagano (2010) highlight that expansionary monetary policy may have fueled oil price increases, but also report that it appears to exert its impact through expectations of higher inflation and growth rather than on the flow of global liquidity into oil futures markets. By identifying both fundamental and non-fundamental oil shocks, we are able to balance the importance of fundamentals against that of inefficient financial activity.

The remainder of this paper is organized as follows. In the next section we cast a formal definition of destabilizing financial activity in a simple theoretical framework and argue that it is necessary to include futures markets in the analysis of the role of financial speculation. We describe the VAR model specification and the identification strategy in

[2] See Sanders et al. (2004) for a more detailed explanation.

[3] Irwin and Sanders (2010), for example, proxy index fund positions by swap dealer positions to evaluate the impact of index funds on commodity futures markets. Although this is a fair approximation for agricultural commodity markets, this is not the case for energy markets as swap dealers operating in energy markets only conduct a limited amount of long-only index swap transactions (CFTC 2008).

Section 3, and discuss the empirical results in Section 4. Section 5 concludes.

2 Understanding financial activity in oil futures markets

2.1 The oil futures market

Futures markets exist as a means of transferring risks of price fluctuations. Typically, traders in the oil futures market are divided in two categories, i.e. commercials and non-commercials. Agents who deal with physical oil, often labeled as *commercials*, may wish to hedge against price fluctuations by fixing in advance the price they will have to pay or receive for a delivery in the future. Yet, agents not dealing with physical oil also participate in the market, making the oil market more liquid. These *non-commercials* intervene in oil futures market because they want to achieve exposure to oil price risk, either on the upside or downside, to make a profit. Typically, speculation in the oil market is attributed to the financial activity of traders that actively enter the futures market and buy or sell according to (expected) fundamentals. The Commodity Futures Trading Commission (CFTC) ascribes speculative activity to non-commercial traders placing bets based on their expectations of the future oil supply-demand balance. Without relying on trader position data, Kilian and Murphy (2010) also define speculation in the oil market as related to oil fundamentals, i.e. a speculation shock in their framework is *"any oil demand shock that reflects shifts in expectations about future oil production or future real activity (p.9)"*.

In reality, however, movements in futures prices may not always reflect efficient pricing of the expected oil supply-demand balance. For example, agents may intervene in the futures market because they want to allocate part of their portfolio to oil. Commodity-related index funds were created to allow investors to easily achieve exposure to commodity price risk, and accordingly they only enter on the long side of the futures market, independent on whether future oil fundamentals are strong or weak. The magnitude of the inflows into such index funds is precisely one of the reasons why many observers attributed the recent volatile behavior of oil prices to speculation. This type of speculation, or more generally financial activity, is not captured by looking at non-commercial positions because index fund traders are regarded as commercial traders. Neither is it specifically captured in the framework employed by Kilian and Murphy (2010).[4]

[4] The scheme used by Kilian and Murphy (2010) to identify the speculation shock is possibly consistent

Therefore, we define destabilizing financial trading in oil markets based on identifying two types of financial activity in the oil futures market. The first type occurs on the back of changing expectations about *oil market fundamentals*. This does not distort the efficient functioning of the oil market, but rather enhances the oil price formation mechanism by bringing in new information on expected fundamentals. Conversely, the second type of financial activity occurs independently of (current and expected) oil supply and demand fundamentals, thereby distorting efficient pricing in the futures and spot market by causing prices to deviate from their levels justified by fundamentals. Only this type of inefficient financial activity matters to policy makers and regulators. Although it is possible that speculative traders bet on oil prices going in a similar direction than fundamentals, they will create more demand for futures than is justified by demand and supply in the physical market for oil. We define this type of trading as *destabilizing financial activity*. In the next subsection, we characterize these two types of financial activity by analyzing the theoretical link between the oil spot and futures market.

2.2 The link between spot and futures prices

Financial activity in the futures market only matters if changes in futures prices can affect oil prices in the spot market. This linkage between the spot and the futures market for oil is commonly represented by a *no-arbitrage condition* (Pindyck 1993, Alquist and Kilian 2010). We start from this condition to give a theoretical characterization of the two types of activity in futures markets (efficient versus inefficient), which will also prove useful for the identification of these shocks later on.

Let us consider an investor who holds P_t units of the numeraire at time t. He can either invest in a risk-free bond with yield r_t, or buy oil, store it and sell it on the futures market for delivery in $t + \tau$. Buying oil, however, also brings an additional benefit in that the investor has access to a commodity that he can exploit, if needed. We will label this benefit as the *convenience yield*, and denote it as $\psi_{t,t+\tau}$ (Pindyck 1993). By the no-arbitrage principle, the two investment strategies should bear the same return. If we

with the way we identify the inefficient financial shock later on, under the condition that inefficient financial trading contemporaneously affects oil prices and inventories in the spot market and the no-arbitrage condition holds. However, our aim is to focus on non-fundamental futures market shocks and remain agnostic about the impact of destabilizing financial activity on oil prices and inventory holdings in the spot market. We discuss this in more detail later on.

denote the spot price as P_t and the future price $F_{t,t+\tau}$, we have:

$$P_t(1+r_t)^{\tau} = F_{t,t+\tau}(1+\psi_{t,t+\tau}) \tag{1}$$

Taking logarithms, and explicitly considering storage costs $c_{t,t+\tau}$, Equation (1) is approximated by:

$$p_t + \tau r_t = f_{t,t+\tau} + \psi_{t,t+\tau} - c_{t,t+\tau} \tag{2}$$

So, if markets are efficient and arbitrage opportunities are exploited instantaneously, Equation (2) would hold. If the convenience yield, net of storage costs, is positive, this will imply that spot prices are higher than futures, which explains why the futures curve in commodities markets is often negatively sloped (backwardation). However, if storage costs are higher than the convenience yield, it would be possible to observe a positive-sloped futures curve (contango). Rewriting Equation (2) gives an expression of the futures price in terms of the spot oil price, the convenience yield, storage costs and the risk-free rate:

$$f_{t,t+\tau} = p_t - \psi_{t,t+\tau} + c_{t,t+\tau} + \tau r_t \tag{3}$$

Pindyck (1994) postulates a relationship between the convenience yield on the one hand, and oil inventories and expected demand on the other:

$$\psi_{t,t+\tau} = G[I_t, E(D_{t,t+\tau})] \tag{4}$$

where I_t is the level of inventories, $E(D_{t,t+\tau})$ is expected net demand over period t to $t+\tau$ and G denotes a generic function.[5] G is decreasing in I_t since at times of low inventories the marginal yield of an additional unit is higher. This conjecture is also supported by the empirical analysis presented by Einloth (2009). At the same time, the level of inventories will also positively affect storage costs. A low level of inventories would imply large availability of storage facilities, while a high level is associated with difficulties in finding storage and rising costs. Hence, following a change in inventories, storage costs and the convenience yield react oppositely, but given that they appear with opposite signs in Equation (3), their impact on the spot price will cumulate. A change in current demand and supply will produce a change in the current level of inventories,

[5] There is no need to specify the functional form of the function G in more detail, as the identification of the different types of oil shocks will only depend on the sign of the relationship between the convenience yield and its determinants. The G function may as well be nonlinear, the only requirement should be that it is monotonic in its two arguments.

which also moves the convenience yield. Conversely, G is increasing in $E(D_{t,t+\tau})$ since higher expected net demand makes holding inventories more appealing as future market tightness is expected. Of course, higher expected demand in the future will also lead to an increase in inventories, which would partially counteract the increase in convenience yield both via the direct impact in the G function and via an increase in storage costs. However, we think it is reasonable to assume that the increase in inventories will not manage to *immediately* offset the positive impact of future tightness on the convenience yield. This is because real-world frictions cause inventory building to take time; agents have to find a producer, a storage facility and wait for shipment. Therefore, in the following we assume that the overall impact at time t of an increase in future market tightness is positive on the convenience yield net of storage costs.[6] Substituting Equation (4) into Equation (3) gives the following:

$$f_{t,t+\tau} = p_t - G[I_t, E(D_{t,t+\tau})] + c_{t,t+\tau} + \tau r_t \tag{5}$$

In the efficient markets case, traders will have access to the same information set and process the flow of news homogeneously, so that Equation (5) will always hold. More specifically, all other things equal, futures prices will be moved by the flow of news on current fundamentals and the level of inventories, as well as by news related to expectations on future demand and supply. Accordingly, we define the efficient futures price as the price which is only driven by oil demand and supply fundamentals.

However, commodity markets are not likely to always function efficiently, which may alter the textbook functioning of the linkage between spot and futures prices. First, not all agents trading in the futures market have access to the same information, or may process the news that they receive differently. Singleton (2011) argues that investors can have different opinions about public information concerning the future course of economic events and their impact on the price of oil. This will generate a dispersion of beliefs that may affect price formation, create higher price volatility and drive the future price away from the efficient level. Second, some agents may place their bets by jumping on local trends, rather than trading based on long-term fundamentals. Hence, there may be players who just enter the market to achieve exposure to commodity price risk. For example, when an index fund receives an inflow by an investor, it will buy oil futures irrespective of its

[6] This point is crucial to understand why, when identifying the different oil shocks later, we only impose the restrictions on the futures-spot spread *on impact*.

expectations on the oil supply and demand balance. Such interventions will also affect the futures price set in the market, thereby generating a *deviation* from the fundamental no-arbitrage relationship, so that the *observed* future price becomes:

$$f^{\circ}_{t,t+\tau} = f_{t,t+\tau} + \epsilon^{f}_{t} \tag{6}$$

where $f_{t,t+\tau}$ is the futures price that would prevail if the no-arbitrage condition was always satisfied and the price was solely determined by fundamental factors, i.e. the one found in Equation (5). The term ϵ^{f}_{t}, which we assume to be weakly stationary, represents the deviation of the observed future price from its no-arbitrage value.[7] This shock ϵ^{f}_{t}, which we will label the *destabilizing financial shock*, creates a perturbation in the futures market in the sense that demand for futures contracts from noise traders moves the observed futures price away from its efficient level.

For the reason that deviations from the no-arbitrage condition may exist, it is necessary to consider futures market activity in assessing the role of financial activity, instead of spot price movements only.[8] This is because all financial shocks occurring in the futures market may not be perfectly reflected in the spot market on impact. Although only futures market activity that eventually affects the spot price matters, only looking at the spot market could lead to incorrect or incomplete identification of the financial speculation shocks we want to pin down. Kilian and Murphy (2010), for example, argue that futures markets are not needed when examining speculation, as they assume that inventories respond on impact following speculation shocks and this impact response contains sufficient information on futures markets activity. Their model is based on the assumption that the no-arbitrage condition holds at any time. However, when we test for this by including futures prices in their model to evaluate whether its reaction is in line with the no-arbitrage condition, we find that this is not the case.[9] More specifically, following the speculation shock that Kilian and Murphy (2010) identify, the futures price does not respond significantly on impact.[10] This implies that their speculation shock can shift spot prices without affecting

[7] The stationarity assumption reflects the idea that misalignments cannot persist indefinitely.

[8] We provide a brief overview of the rapidly increasing literature that deals with deviations from the no-arbitrage condition in the next section.

[9] Although Kilian and Murphy (2010) test for sufficient information in their VAR model using the test proposed by Giannone and Reichlin (2006), we find this is a more intuitive and direct way to test whether we can fully rely on the no-arbitrage condition and exlude the futures markets.

[10] In addition, when we impose the restriction that the futures price should change in line with the no-arbitrage condition, the results and the contribution of the speculation shock significantly change. We used the 3-month futures contract for the replication, the results are available upon request.

the futures price, which is inconsistent with the no-arbitrage condition and the concept of *financial* speculation shocks. Hence, assuming that all relevant financial activity in the futures markets is reflected in changes of inventories may not be empirically grounded. In addition, it is well known that the publicly available inventory data is very poor, and only represents a small part of global oil inventory holdings. This reasoning also applies to the financial speculation shock identified by Juvenal and Petrella (2011), who define speculation as a supply shock in the spot oil market that decreases production, increases inventories on impact and thereby affects the spot price of oil. However, future expected supply tightness such as downgrades in supply projections could also cause oil producers to lower production as they can isell oil at a higher price in the future, and could cause consumers to respond by increasing inventories. Hence, also this type of shock is not necessarily driven by increased financial activity in the futures market. For this reason, we consider financial activity shocks by identifying shocks to the oil futures price directly, and allowing for deviations from the no-arbitrage condition. In this way, we are more certain that the destabilizing shock actually captures trading activity in the futures markets, and that we cover a wider range of inefficient financial activity.

2.3 The transmission mechanism to spot prices

How can a perturbation to oil futures prices transmit to oil spot prices? In the no-arbitrage framework, if futures prices deviate away from the no-arbitrage condition, arbitrageurs will immediately intervene and realign prices via the inventory channel. Kilian and Murphy (2010) identify speculation as an inventory demand shocks in the spot market, and thereby assume that the no-arbitrage condition holds at any time. As already mentioned before, in reality however, there may be frictions that prevent arbitrageurs to intervene immediately. Such frictions can affect the speed at which misalignments in the oil market can be cleared. For example, there could be physical limits to arbitrage due to the availability of storage facilities, or arbitrageurs may be capital-constrained (e.g. Shleifer and Vishny 1997). Indeed, Acharya et al. (2009) report that the presence of capital constraints to arbitrageurs increases the difference between spot and futures prices.[11] In addition, it could

[11] In the second half of 2008, the futures curve was in a deep contango which offered hugely profitable arbitrage opportunities to investors. Yet, such opportunities could not be seized swiftly and the contango persisted for several months since the accumulation of inventories which followed the slump in demand made the access to storage facilities very difficult.

take time to find a producer who sells and delivers physical oil to the storage facilities. This implies that in reality deviations from the no-arbitrage conditions may persist. In this respect, Mou (2010) reports that index funds activity is able to significantly move futures prices around the roll-over dates, and that in spite of the dates being known in advance, arbitrageurs do not immediately intervene to exploit the misalignment between spot and futures prices. Also in futures markets, limits to arbitrage can exists because of financial market imperfections that affect the flexibility of traders to finance their commodity positions (Singleton 2011).

The futures price observed on the market is part of the information set of all players in the physical market. How would such players react to changes in futures prices away from the efficient level? Given that agents have different information sets and heterogeneous beliefs, some of them may correctly recognize this as a misalignment, and hence try to arbitrage away the difference by changing their inventory holding decisions. Others may instead interpret the price signal as genuinely related to changing expectations on fundamentals, and adjust their supply and demand decisions. Moreover, it could also take some time for the agents in the spot market to recognize and interpret this deviation. Finally, oil futures prices are used as a reference price at which current contracts are made, which causes fluctuations in oil futures prices to directly feed into spot prices via indexation, without the need of an immediate quantity adjustment.

A priori, it is thus not exactly known how and via which channel a change in the futures price following a destabilizing speculation shock is transmitted to the spot market, and therefore we remain agnostic on this. More specifically, we decide to leave the response of the spot price, oil production and oil inventories over to the data in the empirical part. What we do know is that the destabilizing financial shock has an impact on the spread. Let us substitute Equation (5) into Equation (6) to get:

$$f^{\circ}_{t,t+\tau} = p_t - G[I_t, E(D_{t,t+\tau})] + c_{t,t+\tau} + \tau r_t + \epsilon^f_t \tag{7}$$

According to Equation (7), the observed futures price is a function of the spot price, current and expected changes related to fundamentals (i.e. the current level of inventories, which is influenced by current and expected demand and supply and also determines storage costs) and the destabilizing financial shock. Futures are thus allowed to vary following current or expected changes to oil supply and demand as well as to destabilizing financial activity in the futures market. Hence, Equation (7) captures the two types of activity in oil futures markets described above in Section 2.1.

To see this more clearly, let us rewrite Equation (7) in terms of the observed futures-spot spread:

$$s^{\circ}_{t,t+\tau} = f^{\circ}_{t,t+\tau} - p_t = \underbrace{-G[I_t, E(D_{t,t+\tau})] + c_{t,t+\tau} + \tau r_t}_{(1)} + \underbrace{\epsilon^f_t}_{(2)} \tag{8}$$

where $s^{\circ}_{t,t+\tau}$ is the observed futures-spot spread between t and $t+\tau$. This equation expresses the spread in terms of an efficient component (1) and a component (2) that takes into account destabilizing financial activity and the chance that prices may be misaligned with respect to the level warranted by (current and expected) fundamentals.

The spread will respond differently depending on the type of oil shock. First, consider a (temporary) tightening in the current supply-demand balance, e.g. an unexpected supply shortfall because of unrest in an oil-producing country, or a sudden increase in oil demand. These shocks will produce a drawdown of inventories, which in turn increases the convenience yield and decreases storage costs.[12] Therefore, term (1) in Equation (8) will be lower, and the spread will decline. In other words, spot prices will increase more that futures prices do. For oil markets observers, it should not come as a surprise that a negatively-sloped (backwardated) futures curve is associated with a situation of market tightness which produces high convenience yields.

Second, a shock to expected fundamentals such as higher expected oil demand in emerging economies will also shift the convenience yield upwards. As mentioned before, such a shock is likely to cause inventory accumulation, which would partly counteract the initial increase. However, changing inventory holdings takes time due to frictions, which causes that *on impact* an increase in the expected market tightness will cause a reduction of the spread. It is possible that after some time, as soon as inventory accumulation materializes, the decline in spread may be counteracted by the effect of the inventory accumulation, but in terms of our identification strategy we remain agnostic on the response of the spread beyond the point of impact. The fact that the convenience yield should increase following an increase in expected tightness in the physical market is also reported in Pindyck (2001),

[12] In the empirical part, however, we do not restrict inventories because of the poor coverage of the inventory data available and because these sign restrictions are not needed to uniquely disentangle the different oil shocks.

and our argument is in line with his.[13]

Finally, a destabilizing financial shock such as an inflow of an index fund or technical trading out of line with fundamentals will act through term (2) in Equation (8) and push up the spread in absence of changes in the convenience yield. After the shock has hit the futures markets, agents may possibly adjust their inventory holdings and their demand and supply decisions, which may eventually lead to changes in the convenience yield. However, the contemporaneous impact of such a shock on the spread will be positive. The fact that the futures-spot spread reacts differently to the two different kinds of activity in the futures market (i.e. trading based on fundamentals and destabilizing financial activity) will prove crucial to uniquely identify these shocks and their importance later on.[14]

To evaluate whether movements in the spread have been related to inflows into index funds, we regressed the changes in the spread on a constant and the inflows into commodity-related index funds as estimated by Barclays. The data used for this simple exercise is monthly and covers the period 2007:01- 2010:02. Although the sample size is very short, and the overall R^2 of the regression is low (8.4%), the regression results suggest that the coefficient on the inflows is positive and significant at the 10% level.[15] This indicates that using the impact of non-fundamental trading on the spread, which is key to our identification strategy, is supported by the data.

3 Model specification and identification

Although the importance of financial activity in determining oil price fluctuations is still strongly debated, it is common knowledge that, at least in the long run, oil fluctuations are mainly driven by changes in oil supply and demand. In order to get a comprehensive

[13] Pindyck (2001) actually uses an increase in expected volatility as an example, but he maintains that an increase in expected tightness in the physical market will have the same type of impact.

[14] Note that although the risk-free rate is part of the fundamental component, it positively affects the spread and therefore could be wrongly identified as part of the destabilizing financial shock. However, based on our results, the correlation between the structural financial shock and various measures of the risk-free interest rate is negligible. In addition, if we regress the financial shock on the interest rate we fail to find significant results, which indicates that we are not confusing inefficient financial shocks with shocks to the interest rate. Regressing the financial shock on inventories also generates insignificant results.

[15] The estimated coefficient is also economically significant. For example, one USD billion of index fund inflows raises the spread by 0.2 USD. Given that in non-turbulent times, inflows are around 4-5 USD billions, this impact is non-negligible.

view on the determinants of oil prices, we will identify oil price movements that are driven by conventional oil supply and demand shocks in addition to those related to destabilizing financial activity.

3.1 A structural VAR model

To evaluate the role of the different types of shocks in determining the oil price, we employ a structural vector autoregression (SVAR) framework that has the following general representation:

$$X_t = c + A(L)X_{t-1} + B\varepsilon_t$$

The vector of endogenous variables X_t captures the global dynamics in the oil spot and futures market by including world oil production (Q_{oil}), the price of crude oil expressed in US dollars (P_{oil}), a measure of world economic activity (Y_w), the futures price of oil (F_{oil}) and oil inventories (I). To avoid redundant variables, we do not include the spread ($s_{t,t+\tau}$) in the model, but generate the response as the difference between the estimated level response of the futures and spot price of oil. c is a vector of constants, $A(L)$ is a matrix polynomial in the lag operator L and B is the contemporaneous impact matrix of the vector of orthogonalized error terms ε_t. The oil price is the nominal Brent crude oil spot price and the futures-spot spread is based on the associated 3-month futures contracts. Although the Brent futures market is somewhat thinner than the WTI market, we use the Brent oil price as a global benchmark for the reason that WTI oil is mainly used in the US, and its most recent price movements were mainly reflecting regional surplus inventory capacity at the delivery point of the contract (Cushing, Oklahoma). We proxy global economic activity by the OECD measure of global industrial production, which covers the OECD countries and the six major non-OECD economies, including e.g. China and India. Following Kilian and Murphy (2010), we proxy global crude oil inventories as total US crude oil inventories, scaled by the ratio of OECD petroleum stocks over US petroleum stocks.[16] The VAR model is estimated using monthly data over the sample period 1991:01-2010:02, and we include 12 lags of the endogenous variables.[17] All the

[16] We do not include the US Strategic Petroleum Reserves in our measure of inventories.

[17] Although lag selection criteria propose to only include 2 or 3 lags, we decide to include one year of lags; this is required to allow for enough dynamics in the macroeconomic variables following an oil shock, see Hamilton and Hererra (2004). The start of the sample period is determined by the availability of futures price data.

variables are transformed to monthly growth rates by taking the first difference of the natural logarithm and are corrected for seasonality. In general, the results are robust to different specifications of the variables and the SVAR model, see the discussion in Section 4.4.

3.2 Identification of different types of oil shocks

The recent literature has clearly shown that different factors can drive oil price movements, and that the economic consequences crucially depend on the underlying source of the oil price change (Kilian 2009; Peersman and Van Robays 2009, 2012). We identify four different types of shocks: an oil supply shock, an oil demand shock driven by economic activity, an oil-specific demand shock (i.e. the fundamental shocks), and a destabilizing financial shock (i.e. the non-fundamental shock). We do this by relying on the following set of sign restrictions:[18]

STRUCTURAL SHOCKS	Q_{oil}	P_{oil}	Y_w	I	F_{oil}	$s_{t,t+\tau}$
Non-fundamental shocks						
Destabilizing financial activity					≥ 0	≥ 0
Fundamental shocks						
Oil supply	≤ 0	≥ 0	≤ 0		≥ 0	≤ 0
Oil demand driven by economic activity	≥ 0	≥ 0	> 0		≥ 0	≤ 0
Oil -specific demand	≥ 0	≥ 0	≤ 0		≥ 0	≤ 0

First, we disentangle the fundamental oil shocks from the non-fundamental financial shocks. We do this by imposing opposite signs on the impact response of the spread, based on Equation (8). The fundamental shocks which increase oil prices have a negative effect on the futures-spot spread, whereas destabilizing financial activity increases the spread after increasing the futures price of oil.[19] Hence, we define the *destabilizing financial shock* as a

[18] The sign restrictions are shown for oil shocks that increase the oil futures price. A more detailed explanation on the use of sign restrictions can be found in the appendix.

[19] In order to disentangle the fundamental versus the non-fundamental shocks, we only look at the change in the spread, i.e. the difference between the change in the level of the futures price and the change in the level of the oil spot price. The restriction imposed on the spread does thus not imply that the market should be in contango or backwardation.

shock to the futures markets that raises the oil futures price and increases the futures-spot spread. This could for example reflect the trading behavior of index funds that enter the oil futures market irrespective of oil market fundamentals, or technical analysts that jump on price trends. We only impose the sign restrictions on the spread on impact, for the reason that the arguments presented in Section 2.3 to motivate our identification strategy via the spread only relate to its immediate reaction.[20] Also note that we do not restrict any of the responses in the oil spot market following a destabilizing financial shock, as the effect on the oil spot market and the exact transmission mechanism is a priori unknown.

Second, we further disentangle the fundamental shocks into shocks caused by shifting oil demand and oil supply. Following Baumeister and Peersman (2010) and Peersman and Van Robays (2009, 2012), we disentangle the fundamental oil supply and oil demand shocks by relying on a set of signs derived from a simple supply-demand scheme of the oil market. Shocks on the supply side of the oil market shift the oil supply curve and therefore move oil prices and oil production in opposite directions. Shocks on the demand side of the oil market shift the oil demand curve and therefore cause oil prices and oil production to move in the same direction. More specifically, an unfavorable *oil supply shock* is an exogenous shift of the oil supply curve to the left which lowers oil production and increases oil prices, whilst world industrial production does not increase. Exogenous oil production disruptions caused by geopolitical tensions in the Middle-East are a natural example. Consistent with the no-arbitrage condition, oil futures prices will increase after this shock, but less than proportionally, so that the futures-spot spread declines. This is because the convenience yield will also be higher after the increase in oil spot prices driven by the oil supply shock.

In contrast, a favorable *oil demand shock driven by global economic activity* and the accompanying rise in overall commodity demand will increase both oil production and oil prices as this shock is represented by an upward shift of the oil demand curve. By definition, such shocks are associated with an increase in global economic activity. A natural example of this type of shock is the surge in oil demand on the back of strong economic growth in emerging economies such as China and India. Again, to satisfy the no-arbitrage condition, the futures price will increase and the futures-spot spread will decline.

[20] In contrast to the restrictions on the spread, restrictions on the other variables are imposed for a period of 12 months, similar to Peersman and Van Robays (2009, 2012).

Finally, an unfavorable *oil-specific demand shock* is a demand shock for oil which is not driven by stronger economic growth. This shock also raises oil prices and oil production, but is associated with a negative, or rather non-positive, effect on economic activity. As this oil price increase is also driven by (expected) fundamentals, the futures price will increase and the spread will decline according to the no-arbitrage condition. Two examples of this are an oil substitution shock and a shock to expected oil fundamentals. Rising demand for oil caused by increased substitution of nuclear power for oil will drive up the price of oil, increase oil production and will not be favorable for economic activity because of the higher oil price. On the other hand, an expected fundamental shock, e.g. tighter expected oil supply or demand, will raise oil demand due to an increased demand for oil inventories. This will increase both the oil price and production, and will not stimulate economic activity as oil prices are higher. However, we do not restrict the response of inventories following the oil-specific shock to capture a broader set of oil-specific demand shocks beyond these expected fundamental shocks.[21]

As we only identify four oil shocks using a five-variable SVAR model, a residual shock captures the structural shocks not accounted for. This residual shock has no direct economic interpretation, and based on the results described in the next section, its importance in explaining oil spot and futures prices appears to be small.

4 Empirical results

4.1 Effects of different types of oil shocks

Figure 1 shows the estimated 68 percentage confidence bands of the impulse response functions to the different types of oil shocks. The estimated responses are shown in levels up to 60 months following a one standard deviation shock. We find it convenient to also show the estimated median response as a possible summary measure, even though the median responses are prone to some criticism and should therefore be interpreted with caution (see Fry and Pagan 2010 for more details).[22]

[21] Kilian and Murphy (2010), in contrast, separately identify an expected oil fundamental shock in their SVAR model identified with sign restrictions, which they label as the speculation shock. In our framework, however, we consider the expected oil fundamental shock as one that still reflects efficient market functioning, and is part of the more general fundamental oil-specific demand shock.

[22] The results based on the 68 percentage range are not subject to this critique as they describe a range of possible outcomes.

Similar to Kilian (2009) and Peersman and Van Robays (2009, 2012), we find that the dynamics of an oil price increase crucially depend on the underlying source of the increase. First, the exogenous *oil supply shock* causes oil production to decline and oil prices to increase permanently. A temporarily lower level of inventories partially counterbalances the fall in oil supply, although not significantly, and the oil supply shock permanently reduces the level of economic activity. The dynamics of the response of the oil futures price is very similar to those of the oil price in the spot market, although the futures price increases by less so that the spread declines. This decline is only temporary, indicating that following the oil supply shock, the slope of the oil futures curve does not significantly change in the somewhat longer term. Second, the permanent oil price increase caused by a *shock in oil demand driven by economic activity* is associated with a permanent increase in oil production and a positive effect on industrial production, which is not surprising given that this shock is identified as an aggregate demand shock that boosts demand for oil. Oil inventories tend to decrease temporarily to partially accommodate for the increased demand for oil, although this decline is not significant. Again, the response of the oil futures price is very similar to the one of the spot price, and the spread temporarily declines. Third, the *oil-specific demand shock* also causes oil spot prices to be permanently higher. The increased demand for oil raises oil production and has a permanently negative effect on the level of economic activity. Oil inventories do not respond significantly, which is probably due to the fact that this shock captures a wide variety of oil-specific demand shocks with diverging effects on inventories.[23] Again, the spread only declines in the short run. A one standard deviation oil demand shock driven by economic activity raises oil prices with about 4 percent on impact, which is somewhat higher than the impact effect of a shock to oil supply and oil-specific demand.

Interestingly, not only the fundamental shocks, but also the destabilizing financial shock affects oil spot prices significantly. As expected, this effect on the oil spot price is only short-lived, in contrast to the oil price responses following the fundamental shocks which are permanent. The impact of a typical destabilizing financial shock on the oil price is about half the size as one driven by economic activity. The pass-through of the destabilizing financial shock in futures prices to the spot market price for oil is incomplete,

[23] For example, an expected fundamental shock is likely to increase inventories as agents in the physical market want to anticipate the future oil price increase, and a substitution shock is more likely to decrease oil inventories because of the unexpected increase in oil demand.

and the futures-spot spread increases permanently.[24] We do not find a significant reaction of oil production or oil inventories, nor do we find that destabilizing financial activity has real economic effects.[25] The non-significant response of oil inventories is interesting given the current discussion in the literature on the relationship between inventories and speculation. Much of the anecdotal evidence against a role of speculation is that during the past few years, there was no noticeable increase in inventories (e.g. Irwin and Sanders 2010). However, using a simple theoretical model, Hamilton (2009) shows that speculation can affect spot oil prices without triggering a significant rise in inventories as long as the price elasticity of oil demand is small. We find that financial activity is indeed *not* necessarily associated with a significant change in inventories but can still affect the spot price of oil, if speculation is defined as inefficient trading in the futures market.

4.2 Relevance of different types of oil shocks

The impulse response analysis shows that destabilizing financial activity in the futures markets can matter as it significantly affects spot oil prices. The forecast error variance decomposition will shed some light on the overall importance of destabilizing financial trading for explaining the variability of oil spot prices over our sample, relative to the fundamental shocks. Figure 2 shows this forecast error decomposition of the oil spot price and the oil futures price. The variance decompositions are obtained using the posterior median draws at each point over the forecast horizon.[26]

The left-hand side of Figure 2 displays the forecast error variance decomposition of the oil spot price. It is clear that the largest part of oil price fluctuations over our sample are explained by shocks to fundamentals. Over short forecast horizons, more than 90 percent of the forecast error is attributable to fundamental shocks in oil demand and supply. Not surprisingly, oil demand shocks driven by economic activity account for most of this

[24] This confirms our conjecture that it is necessary to include futures market variables in the model when assessing the role of financial speculation, since relying on a full pass-through of futures price shocks to oil spot prices via the no-arbitrage condition is not supported empirically.

[25] The non-significant response of production can not be conclusive on the validity of the Hotelling principle, which argues that oil producers have the tendency to keep oil production in the ground as futures prices are higher than spot prices. We would expect this effect to play only when the market is in contango, i.e. spot prices are lower than futures prices.

[26] We refer to Section 4.4 for robustness checks on alternative choices of this specific draw. The forecast error decompositions of the other variables in the SVAR model are available on request.

contribution, explaining more than 40 percent of the forecast error variance. Shocks to oil supply account for about 30 percent of the forecast error in the short run, which however declines in the longer run. Clearly, this implies that the importance of non-fundamental financial shocks is rather limited. Over different forecast horizons, the destabilizing financial shocks accounts for about 10 percent of the forecast error decomposition on average. Although this contribution is very limited relative to those of the fundamental shocks, inefficient trading can account for a non-negligible part of oil price variability.

The right-hand side of Figure 2 shows the forecast error decomposition of the futures price. Destabilizing financial activity plays a significantly larger role in explaining futures price movements, contributing more than 20 percent to the forecast errors at very short horizons. This contribution declines somewhat at longer horizons, reaching 16 percent in the long run. Futures price variability is also for most part explained by shocks to (expected) fundamentals, and by oil demand shocks driven by economic activity in particular. The smaller contribution of the destabilizing financial shock in the spot market indicates that not all inefficient trading in the oil futures markets is passed on to the oil spot market, which is consistent with the incomplete pass-through of the destabilizing financial shock to oil spot prices found in the impulse response analysis. Finally, note that the contribution of the non-identified residual shock is very small in the short run, implying that the four shocks identified in our framework capture almost the entire short-run forecast error variability of oil spot and futures prices over our sample.

4.3 Explaining recent oil price fluctuations

Although inefficient financial trading only explains a limited part of the overall oil price variability over our sample, speculative activity could still be important for understanding the fluctuations in oil prices over the last decade, and during 2007-2008 in particular. To assess these contributions at each point in time, it is useful to look at the historical decomposition together with the nominal oil spot price in USD per barrel given in Figure 3. The historical decompositions are obtained from the posterior median draw.[27] The historical contributions are accumulated and expressed in percentage deviations from the baseline unconditional forecast excluding the structural shocks. A declining contribution is associated with a negative shock that reduces oil prices, and vice versa. For the reason that the more recent period is of main interest, and the financialization of the commodity

[27] We refer to Section 4.4 for the robustness of the results of the historical decomposition to this choice.

markets gained momentum from 2000 on, we concentrate on the evolution of the oil price over the period 2000:01 - 2010:02.[28]

In 2001, after having fluctuated around USD 25 per barrel in 2000, oil prices declined owing to a series of negative global oil demand shocks due to a slowdown in economic activity. This decrease in oil demand can be related to the global decline in GDP growth in 2001 in the context of the early millennium slowdown. Since early 2002, however, oil prices surged with increasing momentum to reach about USD 120 per barrel in June 2008, before plummeting to around USD 45 per barrel in the aftermath of the financial crisis which hit the global economy in the summer of 2008. Figure 3 clearly shows that the continued increase in oil prices from 2002 till mid 2008 is mainly caused by positive oil demand shocks driven by growing economic activity, which pushed oil prices more than 30 percent higher than the baseline projection over this period. It is well known that the emerging economies became increasingly important as major oil importers since the early 2000s. Accordingly, strong economic growth in the emerging economies which boosted demand for commodities in general can explain most part of the surge in oil prices over this period.[29] This rising demand came against the background of increasing tightness in oil supply when global oil production began to stagnate in 2004, mainly due to non-OPEC countries. Therefore, negative oil supply shocks also contributed significantly to the surge in oil prices, causing them to be about 12 percent higher than the baseline projection between 2003 and mid-2008. Oil-specific demand shocks lifted oil prices higher by more than 20 percent, which makes the total contribution of oil demand shocks in general clearly dominant. Although the contribution of the oil-specific demand shock is compatible with a variety of interpretations, one possibility is increased demand for oil driven by a tighter expected oil supply-demand balance in the future.

There is some consensus that steeply rising oil demand together with tighter oil supply are the driving factors behind the gradual increase in oil prices since 2003 (Hamilton 2009). On the factors behind the strong fluctuations in the oil spot price between 2007 and the beginning of 2010, there is less clarity. Hamilton (2009) finds that it is possible to explain the main part of the oil price run-up in 2007-2008 based on fundamentals, i.e. strong demand confronting stagnating supply. Using a simple theoretical model,

[28] The contributions are normalised to zero in 2000:01. The historical decomposition of the oil price and the other variables in the model over the full sample period are available upon request.

[29] Also Baumeister and Peersman (2008), Hamilton (2009), Kilian (2009) and related papers find that shocks to oil demand are mainly responsible for the continued increase in oil prices since 2003.

however, he argues that speculation could have played a role as well in exacerbating price fluctuations, although fundamentals are likely to be more important. By testing this within an empirical framework, we find similar results for destabilizing financial activity. Figure 3 clearly shows that the considerable rise in oil prices was due to a series of oil demand shocks driven by economic activity, together with increasingly tighter oil supply which aggravated the upward move in oil prices. This can be linked to the observation that the capacity utilization rate at which OPEC was producing increased, leaving less room to absorb unexpected oil demand shocks. Interestingly, we find that also financial activity plays an important role in explaining the steep oil price run up in 2007-2008, and pushed oil prices about 12 percent higher than the level justified by fundamentals over the period 2007:08 - 2008:06. This could be associated with the relevant inflows into passive exchange-traded funds linked to commodities.

In the second half of 2008, oil prices dropped by 62 percent from peak to trough on the back of a slowdown in economic activity and the onset of the financial crisis. Figure 3 indicates that this period was characterized by a substantial fall in oil demand on the back of slowing economic activity, whereas global oil production remained tight. Again, inefficient financial trading contributed significantly to the fall in oil prices, leading to an undershooting of more than 20 percent with respect to the baseline projection over the period 2008:07 - 2008:12. This came against the background of massive outflows from passive index funds due to the onset of the global financial crisis which led many agents to unwind their positions in risky assets to reduce their leverage. In the beginning of 2009, oil demand started to increase again on the back of a recovering global economy, which explains most part of the rise in oil prices since then.

In a nutshell, we do find that destabilizing financial shocks played a role in explaining oil price fluctuations over the last decade. Over the period 2000-2009, in which the volume of crude oil derivatives traded quintupled, inefficient activity in the futures market pushed oil prices about 15 percent above the level justified by (current and expected) oil fundamentals. Particularly in 2007-2009, destabilizing financial shocks exacerbated the gyrations of oil prices. However, it is clear that shocks to oil demand and supply remain the most important determinants of oil price movements.

4.4 Robustness of the results

In this section, we assess whether the main conclusions of the paper still hold for reasonable changes in the specification of the SVAR model. More specifically, we will evaluate whether it is still the case that the destabilizing financial shock (i) affects the oil spot price significantly but has no real economic effects and (ii) only plays a limited role in explaining the variability in oil futures and spot prices over our sample because oil fundamentals are far more important. Moreover, we test whether the inefficient financial trading shock (iii) contributed to the recent oil price fluctuations, and caused oil spot prices to significantly overshoot and undershoot their fundamental level in 2007-2009, although (iv) most of the evolutions of the oil price over the last decade are explained by rising oil demand together with increasingly tight supply.

First, the conclusions are robust to using real oil prices, different maturities for the futures contracts (i.e. 2, 6 and 12 months-ahead futures), the global economic activity measure based on cargo freight rates proposed by Kilian (2009), and reasonable variation in the number of lags for the endogenous variables in the VAR given our sample period (9 and 18 lags). Specifically, the contribution of the destabilizing financial shock to the oil spot price over the period 2000:01 - 2008:06 ranges between 14 and 23 percent for the different specifications tested compared to 15 percent for our benchmark specification.[30] Estimating the model up till 2007 to exclude the most recent volatile period and specifying the model in levels does not alter the main results either.

Second, a well-known critique on the sign restriction methodology concerns the way in which the results are summarized. For the reason that the sign restrictions methodology does not generate a unique model, the impulse response functions are often based on the median of the posterior distribution. However, Fry and Pagan (2010) demonstrate that the impulse response functions could come from different models, which implies that the shocks implicit in the impulse response functions are not necessarily orthogonal. To test for this, we generate the variance decomposition and the historical decomposition of the benchmark VAR model based on the 'closest-to-median' draw proposed by Fry and Pagan (2010), which preserves the orthogonality between the shocks.[31] The results are shown in

[30] The contribution of the destabilizing financial shock is 16.8, 16.9, 14.3, 14.5, 17.2, 13.9 and 22.6 for the specification with real oil prices, 2-, 6- and 12 month ahead futures, the economic activity indicator proposed by Kilian (2009) and using 9 and 18 lags for the endogenous variables respectively. More detailed results are available upon request from the authors.

[31] We only show the results for the variance decomposition and the historical decomposition as the

Panel A of Figure 4 and 5. Although the overall importance of the destabilizing financial shock reduces somewhat when using the closest-to-median draw, the main conclusions of the paper are unchanged.

However, the unique draw proposed by Fry and Pagan (2010) could still lead to the choice of a specific model which generates results that are qualitatively very different from those of the other models satisfying the sign restrictions. Therefore, we narrow the number of admissible models down by imposing additional restrictions on the bounds of the short-run price elasticity of oil supply and demand, as suggested by Kilian and Murphy (2012). We restrict the impact price elasticity of oil supply to be lower than 0.025 and the impact price elasticity of oil demand in production to lie between -0.8 and 0, similar to Kilian and Murphy (2010). The results for the variance decomposition and the historical decomposition are shown in Panel B of Figures 4 and 5. Although the variance decomposition indicates a modest change in the relative importance among the fundamental shocks, in favor of the oil-specific demand shock, the historical decomposition shows that recent evolutions in the oil price are still explained by rising oil demand and tightening oil supply. Moreover, the destabilizing financial shock remains a non-negligible factor in the explanation of the fluctuations of oil prices over time, and in 2007-2009 in particular.

5 Conclusions

We analyzed the role of financial activity in determining the price of oil over the past two decades. As the activity of financial investors in oil futures markets can at the same time enhance and distort the price-setting mechanism in the oil market, we distinguish between two types of activity in the oil futures market. The first type of trading occurs on the back of fundamentals, and therefore makes price formation in the oil markets more efficient. We identify three types of fundamental shocks, i.e. an oil supply shock, an oil-demand shock driven by economic activity and an oil-specific demand shock. Each shock has different effects on the oil spot market variables and global economic activity.

The second type of activity in the futures market occurs independently of oil fundamentals and distorts the price signals in the oil market. We label this shock as a destabilizing

impulse response functions describe a range of possible outcomes which is not in violation of the Fry and Pagan critique.

financial shock, and define it as a deviation from the no-arbitrage condition which captures trading that is not consistent with movements in oil supply and demand. We argue that for properly capturing financial trading in the oil futures markets, it is necessary to include the futures price in the analysis instead of relying on perfect passthough from futures markets to spot markets. In our view, our identification scheme enables us to study the role of financial activity in the oil market more comprehensively than the literature has done so far. Moreover, as only financial activity that distorts efficient price formation is not desirable, we argue that also this type of trading is more relevant for policy makers and regulators. We disentangle the different types of oil shocks using a structural VAR model of the global oil spot and futures market, for which the identification restrictions are derived from a simple theoretical model.

Financial trading in futures markets matters as it can significantly destabilize oil spot prices. The deviation from the fundamental level is only temporary, and the destabilizing financial shock has no real economic effects, nor does it necessarily change inventories. Fundamental shocks, in contrast, push oil prices permanently higher. Most of the evolution of the oil price over the past two decades can be explained by market fundamentals, including the climb in prices during 2002-2008 and the steep fall following the financial crisis. Destabilizing financial trading only exacerbated the movements in the oil price driven by shocks to oil supply and demand, which was the case in 2007-2009 in particular, and its contribution in explaining oil spot prices is limited to about 10 percent. The dominance of market fundamentals in explaining the price of oil indicates that increased regulation on oil futures trading would probably not be desirable, as it could remove valuable liquidity and risk-absorbing capacity from the futures market.

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Appendix

Sign restrictions in practice

As mentioned in the text, we rely on the following structural VAR model to identify the impact of the different types of oil shocks:

$$X_t = c + A(L) X_{t-1} + B\varepsilon_t$$

with X_t the vector of five endogenous variables (oil price, oil production, world industrial production, oil futures price and oil inventories), c a vector of constants, $A(L)$ a matrix polynomial in the lag operator L and B the contemporaneous impact matrix of the vector of orthogonalized error terms ε_t. We want to estimate the effects of four different types of oil shocks, i.e. oil supply shock, oil demand shock driven by economic activity, oil-specific demand shock and the destabilizing financial shock. However, it is not possible to estimate the contemporaneous impact matrix B and therefore identify the structural innovations in ε_t without further assumptions. In particular, since the structural shocks are mutually orthogonal, the variance-covariance matrix of a reduced form estimation of the VAR is $\Omega = B'B$. Given Ω, there are an infinite number of possible B. In the case of sign restrictions, a set of possible B are considered conditional on fulfilling a number of sign conditions. Peersman (2005) shows how to generate all possible decompositions. To uniquely disentangle the four types of oil shocks, we implement the sign restrictions which are explained in Section 3.2. We impose the sign restrictions to hold for the first 12 months after the shocks, except for the response of the spread which is only imposed contemporaneously.

As in Peersman (2005), we use a Bayesian approach for estimation and inference. Our prior and posterior distributions of the reduced form VAR belong to the Normal-Wishart family. To draw the "candidate truths" from the posterior, we take a joint draw from the unrestricted Normal-Wishart posterior for the VAR parameters as well as a random possible block lower triangular decomposition B of the variance-covariance matrix, which allows us to construct impulse response functions. If the impulse response functions from a particular draw satisfy the imposed sign conditions, the draw is kept. Otherwise, the draw is rejected by giving it a zero prior weight. We require each draw to satisfy the restrictions of all four shocks simultaneously. Note that the restrictions following the destabilizing financial shock are only imposed on the futures price and the futures-spot spread, the responses of the spot oil market variables are fully determined by the data. A total of 1000 "successful" draws from the posterior are then used to show the 68 percent probability range of possible impulse responses to the shocks in Figure 1, together with the median response. In general, we need 188179 draws to find 1000 successful identifications, which indicates that the data is relatively in favor of the model that generates the sign restrictions. When imposing additional sign restrictions on the bounds of the price elasticity of oil supply and demand, in line with Kilian and Murphy (2010), we need more than 355000 rotations for finding one successful draw.