Destabilizing Speculation in the Oil Market

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Abstract

In this paper, we assess to what extent speculative activity has contributed to destabilize oil prices in the recent years. Using a structural VAR model identified with sign restrictions, we define destabilizing speculation as a shift in oil prices that is not related to current and expected fundamentals, and thereby distorts efficient pricing in the oil market. We disentangle this non-fundamental speculation shock from fundamental shocks to oil supply and demand to determine their relative importance. We find that speculative trading in the futures market affects spot oil prices significantly, although its overall importance is limited in the long-run. However, speculation did affect oil prices over the past decade, and exacerbated the volatility in the oil market during 2007-2008 in particular, although shocks to oil demand and supply remain more important.

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

JEL Classification : C32, Q41, Q31.

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1 Introduction

Oil price developments have attracted a great deal of attention in the last few years. After having surged with increasing momentum to unprecedented levels between 2003 and 2008, oil prices fell abruptly in the wake of the financial crisis and the subsequent global economic downturn. Since the beginning of 2009, oil prices first stabilized before resuming an upward path. As the oil price is an important determinant of the Consumer Price Index, the evolution of these prices and the driving forces behind them are key for the conduct of monetary policy.

The increase in oil price came against the background of surging demand from emerging economies and stagnating supply from non-OPEC countries (ECB 2010). However, the massive price gyrations experienced in 2008 led many commentators to question the functioning of the price setting mechanism, and to blame the increasing financialization of oil futures markets for the surge in prices. 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, so-called passive funds, whose goal is to provide investors with long-only exposure to oil, have witnessed substantial inflows in the last years (CFTC 2008). This led some to hypothesize that such inflows may have pushed oil prices above the level warranted by fundamentals.

However, empirical evidence of a systematic impact of non-commercial activity on prices is somehow scant. Granger causality tests have failed to highlight an impact of the positions held by non-commercials in futures markets on spot oil prices (IMF 2006), and instead found that causality works in the opposite direction, i.e. price movements lead repositioning by non-commercial agents. Haigh et al. (2007) do not succeed in identifying an impact of hedge funds on oil price volatility and also the International Energy Agency (IEA) has expressed scepticism at the idea that oil prices have been driven by speculative flows (IEA 2009). Using non-public data of the U.S. Commodity Futures Trading Commission (CFTC), Büyüksahin et al. (2008) conducted a wider set of tests and found that the activity of non-commercial agents has helped linking futures and spot prices. On the other hand, several other studies examining the co-movement between future and spot prices, or between financial market and oil market indicators, do find that some overshooting of oil prices above their fundamentally justified equilibrium level took place, at least temporarily (Khan 2009, Miller and Ratti 2009, Kaufmann and Ullman

2009 and Lombardi and Mannucci 2011).

Yet, most of the institutional and academic literature ascribes the recent movements in oil prices to changes in fundamentals. Hamilton (2009) finds that the oil price run-up of 2007-2008 can mainly be attributed to strong oil demand confronting stagnating global oil production, while also the more gradual rise in oil prices over the period 2003-2008 is usually explained by increasing oil demand. Baumeister and Peersman (2008, 2010) show that the price elasticities of oil demand and supply have become much smaller over time, leading to increased oil price responsiveness 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.

A reason why the current literature fails to be conclusive about the role of speculation is that speculation is an elusive concept, and as such is very difficult to translate it into a measure. First of all, the definition of speculation is rather unclear. In principle, a speculator is an agent that trades in order to exploit misalignments between the market price of a certain asset and what he perceives to be a fair price. Hence, speculative behavior is inherently connected with the motivation of each agent participating in the market, which is of course not measurable. In the framework of commodities, an alternative and workable definition relies on the nature of the investor: the CFTC distinguishes non-commercial from commercial activity to proxy the trading activity of speculators in the futures market. The positions held by non-commercial traders are regarded as speculative positions, since such agents are not physically involved with oil and do not use the futures contract to hedge their physical exposure (CFTC 2008). This definition has however some shortcomings. For example, an airline who buys oil futures as it expects higher prices in the future is inherently "speculating", but it will nevertheless fall into the commercial category. Even more worrying, a mutual fund tracking commodity price indexes with the aim of giving investors exposure to commodity price fluctuations will be regarded as commercial, and will not be accounted for when assessing the impact of speculative trading on the oil price via non-commercial activity.

It is indeed the substantial inflows into such index funds what lead many commentators to believe that oil prices were lifted far beyond the level justified by fundamentals, by creating additional demand in the futures market. Hence, the publicly available data on speculative activity is not completely representative of all sorts of financial activity in futures markets, and the distinction between commercial and non-commercial players may be arbitrary in some cases. This is also recognized by the CFTC:

> "[...] the ultimate motivation for trading futures by commercial and non-commercial traders can not be observed. [...] Thus, some of the trading information captured by the commercial trading category may reflect activity that could be characterized more as speculative rather than hedging (CFTC 2008, p.20)".

Nevertheless, several studies rely on this traders' position data to assess the importance of speculation. Instead, studies that want to evaluate the role of the index funds directly also have to rely on rough approximations. Irwin and Sanders (2010), for example, proxy index fund positions by swap dealer positions in the futures market to evaluate the impact of index funds on commodity futures markets.[1] Although this is a fair approximation for agricultural commodity markets, as swap dealers operating in agricultural markets only conduct a limited amount of non-index swap transactions, this is not the case for energy markets. Specifically, on three specific points in time during 2007 and 2008, the CFTC estimated that only 41% of long swap dealer positions in crude oil futures were linked to long-only index fund positions (CFTC 2008), which illustrates the restrictiveness of this assumption.

In a recent contribution, Kilian and Murphy (2010) examine the issue of speculation in the oil market using a structural VAR which does not include data on non-commercial positions. However, their definition of speculation only captures the type of trading activity that is actually benign for price formation in the oil market, which is probably not the policy-relevant question that has been floating around in the last few years. More specifically, they identify speculative trading as an oil inventory demand shock in the oil spot market that is driven by shocks to expected oil demand and supply in the future. Therefore, their speculation shock only captures revisions about expected *oil fundamentals* that necessarily affect the spot oil market. Trading based on (expected) fundamentals will only

[1] A swap dealer acts as a couterparty for a swap agreement, which is an exchange of one asset for a similar asset or liability for the purpose of changing the associated risk or lengthening or shortening maturities. These swaps are usually traded over-the-counter and swap dealers often hedge their swap positions in the futures market.

improve the price formation mechanism in the oil market in the sense that information on expected fundamentals will be priced in more quickly and efficiently.

In reality, however, not all activity in the futures markets is based on fundamentals. For example, the above-mentioned index funds, whose aim is to provide exposure to commodity price risk for hedging against inflation and portfolio diversification purposes, only enter on the long side of the crude oil futures market, independent on whether future oil fundamentals are strong or weak. Because of this, the index funds can distort price formation by causing oil prices to deviate from levels justified by current or expected fundamentals. As mentioned before, the magnitude of the inflows into such index funds is precisely one of the reasons why many observers have blamed speculation for the recent volatile behavior of oil prices, and which is not captured by looking at non-commercial positions, nor in the framework employed by Kilian and Murphy (2010).

In this paper, we assess the role of speculation in the oil market by identifying it in an original way, which does not rely on traders position data. Using a set of simple theoretical equations, we model speculative activity as a non-fundamental shock to oil futures prices, which creates a deviation from the no-arbitrage condition that links the oil futures and spot market. As this speculation shock is not related to (current and expected) oil fundamentals, it distorts efficient price formation in the oil market by driving oil prices away from the levels justified by fundamentals. We will define these unfavorable inefficiency shocks in the futures market as *destabilizing speculation shocks*. Using a structural VAR model identified with sign restrictions, we disentangle these non-fundamental speculation shocks from fundamentals-based shocks to oil supply and demand. Specifically, by elaborating upon the work of Peersman and Van Robays (2009a,b) and Kilian and Murphy (2010), 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 (i.e. the fundamental shocks) and a destabilizing speculation shock (i.e. the non-fundamental shock) by explicitly including futures market variables in the VAR model.

Our results show that destabilizing speculation in the futures market significantly affects the spot price of oil, although its effect is only short-lived. The pass-through from speculative trading in the futures market to the oil price in the spot market is incomplete as the futures-spot spread permanently increases. In contrast, fundamental shocks to oil supply and oil demand cause oil prices to be permanently higher. Over our sample period, destabilizing speculation explains only a small part of the total variability in oil prices, as shocks to fundamentals account for almost 95% of the forecast error variance decomposition in the long-run. In the short run, however, the importance of destabilizing speculation is significantly higher as it explains almost 20% of the forecast error variability of the oil spot price. Moreover, we find that speculation did cause oil prices to diverge significantly from the level justified by oil supply and demand at specific points in time over the past decade, and in 2007-2008 in particular, although innovations to fundamentals still account for most part of recent oil price fluctuations. More specifically, the gradual run-up in oil prices between 2003 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 in 2007- mid 2008, consistent with the results of Hamilton (2009). Nevertheless, speculative activity caused oil prices to significantly 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. Again, most part of the decline in oil prices was driven by a strong unexpected drop in global oil demand, but speculation caused oil prices to decline far below the level explained by the reduction in oil demand. The contributions of the destabilizing oil speculation shock to the oil price over time can be associated with large flows in and out of passive index funds linked to oil. 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.

The paper is organized as follows. In the next section we cast a formal definition of speculation in a simple theoretical framework. We describe the VAR model specification and the identification strategy in section 3, and discuss the empirical results in section 4. Section 5 concludes.

2 What is meant by speculation?

One of the main pitfalls in the analysis of the impact of speculative flows on oil price is the definition itself of "speculation". Although speculation commonly possesses a negative connotation, we can actually separate benign "stabilizing" from unwanted "destabilizing" activity in the oil futures markets. The former relates to the fact that agents intervening in the oil futures market bring their information sets and expectations on future fundamentals into the pricing mechanism, thereby contributing to the price discovery mechanism, in addition to making the markets more liquid. However, if agents place their bets disregarding the expectations on fundamentals, e.g. shift part of their portfolios to commodities as an asset class, the price formation mechanisms can be distorted. In this section, we shed some light on the concept of speculation by looking at the functioning of oil futures markets and the link between the futures and the spot market for crude oil.

2.1 The oil futures market

In the case of commodities, futures markets exist as a means of transferring risks of price fluctuations. Agents physically involved with 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. Oil producers will therefore have the opportunity to secure their income today by selling futures contracts, and oil consumers will buy futures contracts in order to pin down their future costs.

Yet, agents not physically dealing with oil also participate to 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. For example, an agent that expects oil prices to surge on the basis of strong prospects for oil demand may act as counterpart of a producer that wants to sell its future production today, and hence position himself in the long side of the futures contract. By doing so, if oil prices indeed increase, the non-commercial agents can cash in the difference between the higher oil price and what he paid in the futures contract. Conversely, if prices decrease, the agent will face a loss. In this sense, the oil price risk has been transferred from the commercial to the non-commercial. Of course, the mechanism would work the opposite way if the non-commercial agent expects oil prices to decline instead.

The behavior described above is a "textbook example" of speculation; traders actively enter the oil futures market and trade according to (expected) fundamentals. This definition matches with the speculation shock identified in Kilian and Murphy (2010), i.e. *"any oil demand shock that reflects shifts in expectations about future oil production or future real activity (p.9)"*. In contrast to the general perception that speculation is unfavorable, the presence of these type of speculators actually has a *positive* fallout in that it will make the markets more liquid and allow information to be priced in immediately and efficiently.

In reality, however, movements in futures prices do not continuously reflect efficient pricing of the expected oil supply-demand balance. For example, agents may intervene in the futures market not because they have expectations on the future dynamics of oil fundamentals, but rather because they want to allocate part of their portfolio to oil. There are indeed good motivations to do so, as oil is commonly thought to be a hedge against inflation, and to be negatively correlated with stock markets. However, this type of speculation differs from the "textbook definition" above, because it is not related to current and expected fundamentals, and hence distorts efficient pricing in the futures and spot market.

It is customary practice, among practitioners and market commentators, to ascribe speculative activity to non-commercial agents. However, as also said in the introduction, this distinction may not able to disentangle these two types of financial activity: both commercials and non-commercials can trade on the basis of what they expect concerning the future oil price, or can trade futures contracts for other reasons.

To wrap up, we define speculation in oil markets based on identifying two types of 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 fundamentally justified levels. We will define this type of activity as *destabilizing speculation*. In the next subsection, we will exploit the theoretical link between the oil spot and futures market to better characterize these two types of activity.

2.2 The link between spot and futures prices

Speculative activity in the futures market of course only matters if changes in futures prices 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 will rely on this condition to give a theoretical characterization of the two types of activity in futures markets, which will also prove useful for the identification of these shocks later on.

Let us consider an investor who holds P_t units of 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 *convenience yield*, and denote it as $\Psi_{t,t+\tau}$ (Pindyck 1993).[2] By the no-arbitrage principle, the two investment strategies should bear the same return. If we denote the spot price as P_t and the future price $F_{t,t+\tau}$, we have:

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

Taking logs (1) becomes:

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

So, if markets are efficient and arbitrage opportunities are exploited instantaneously, (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 (2) gives an expression of the futures price in terms of the spot oil price, the convenience yield an the risk-free rate:

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

Pindyck (1994) identifies the determinants of the convenience yield, and expresses it as a function of the spot price of oil, inventories and expected fundamentals:

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

where I_t is the level of inventories, $E(D_{t,t+\tau})$ is the expected demand over period t to $t+\tau$ and G denotes a generic function. G is growing in p_t, since higher prices imply a higher convenience in holding inventories, decreasing in I_t since at times of low inventories the marginal yield of an additional unit is higher, and increasing in $E(D_{t,t+\tau})$ since higher expected demand makes holding inventories more convenient, as future market tightness is expected. Note that also expected future supply tightness will increase the convenience

[2] Here, we abstract from the fact that oil has to be stored and this operation has a price, hence the convenience yield will be expressed net of storage costs.

yield of holding inventories. Hence, we can assume that the term $E(D_{t,t+\tau})$ captures the overall effect of expected fundamentals on the convenience yield.

Substituting (4) into (3) gives the following:

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

where $s_{t,t+\tau}$ is the futures-spot spread between t and $t + \tau$, and shows that in the efficient, no-arbitrage case, the futures price depends positively on the current spot price, negatively on expected oil fundamentals and positively on the risk-free rate.

If agents in the economy are homogeneous (and rational), they will all have access to the same information set and process the flow of news homogeneously, so that (5) will always hold. More specifically, all other things equal, futures prices will be moved by the flow of news that changes expectations of future demand and supply, such as an expected depreciation of the US dollar or other fundamental shocks that can affect the future oil supply-demand balance. Based on this news, agents will place their bets in both the futures and spot market and thereby change the futures and spot price according to the no-arbitrage condition. However, and without the need to depart from rationality, players in commodity markets are indeed not homogeneous, in the sense that the market comprises players that participate in it for different reasons. As said in the introduction, index investors do not base their interventions on their expectations on the future supply and demand balance, but rather simply place themselves on the long side of the futures market to offer their customers exposure to oil price risk. When an index fund receives an inflow by an investor, e.g. by someone who wants to invest in commodities to hedge against inflation risks, it will then buy oil futures irrespective of its expectations on the oil supply and demand balance. Conversely, if an outflow from an index fund materializes, e.g. because an investor needs to reduce his leverage, the fund will sell oil futures, again irrespective of fundamentals.[3]

Such interventions will affect the futures price set in the market, thereby generating a deviation from the no-arbitrage relationship, so that the observed future price becomes:

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

with $f_{t,t+\tau}$ the futures price that would prevail if the no-arbitrage condition was always satisfied, i.e. the one found in (5). The term ϵ^f_t, which we assume to be weakly stationary,

[3] More generally, this reasoning will apply to any agent that places his bets irrespective of fundamentals, e.g. uninformed noise traders or technical analysts who try to jump on price trends.

represents the deviation of the observed future price from its no-arbitrage value. This shock ϵ_t^f, which we will label the *destabilizing speculation shock*, creates a perturbation of the futures market in the sense that demand for futures contracts driven by this sort of speculation moves away the observed futures price from its fundamentally justified level.[4] Let us substitute (5) into (6) to get:

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

According to (7), the observed futures price is a function of the spot price, current and expected changes related to fundamentals and the destabilizing speculation shock. So, futures are allowed to vary based current or expected changes to oil supply and demand as well as for destabilizing speculation in the futures market. Hence, (7) captures the two types of activity in oil futures markets defined above in section 2.1.

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

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

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 a fundamental component (1) and a component (2) that takes into account destabilizing speculation and the chance that prices may be misaligned with respect to the level warranted by (current and expected) fundamentals. Assuming that storage costs are constant, changes in (expected) fundamentals will negatively affect the spread, whereas the destabilizing speculation shocks will have a positive impact, since it increases observed futures prices via (6). 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 speculation) will prove useful to uniquely identify these shocks and their importance later on.[5]

[4] In order for the deviation to persist and hence be observable, we must hypothesize that there are frictions (e.g. physical constraints) that prevent agents to immediately arbitrage away the misalignment. In general, we remark that the presence of frictions cannot be interpreted as a source of misalignment in the pricing equations (i.e. they do not constitue per se a shock), but rather they impact on the absorption of misalignments (i.e. the speed at which shocks die out).

[5] 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 speculation shock. However, as long as interest rates are at low levels, and we look at short maturities, this should not matter much.

3 Model specification and identification

So far, we characterized two types of activity in futures markets which have different implications for the functioning of the oil markets, depending on whether they are based on (expected) fundamentals or not. Although the importance of speculation 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 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 speculation.

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:

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

The vector of endogenous variables X_t captures the 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_t). We construct the futures-spot spread ($s_{t,t+\tau}$) within the model as the difference between the futures price and the spot price of oil. c is a vector of constants and trends, $A\left(L\right)$ 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. 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 Hamilton(2009) and 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. The VAR model is estimated using monthly data over the sample period 1991:01-2010:02, and

Indeed, based on our results, the correlation between the structural speculation shock and the risk-free interest rate, proxied by the Federal Funds rate, is only 0.04 and insignificant, which indicates that we are not confiusing speculation shocks for shocks to the interest rate.

we include 12 lags of the endogenous variables. Based on conventional unit root tests, all the variables except for the spread are transformed to monthly growth rates by taking the first difference of the natural logarithm, and the variables are corrected for seasonality. In general, the results are robust to different specifications of the variables and the SVAR model.[6]

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 (Hamilton 2009, Kilian 2009, Peersman and Van Robays 2009a,b). 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 speculation shock (i.e. the non-fundamental shock). We do this by relying on the following set of sign restrictions:[7]

STRUCTURAL SHOCKS	Q_{oil}	P_{oil}	Y_w	I_t	F_{oil}	$s_{t,t+\tau}$
Non-fundamental shocks						
Destabilizing speculation					≥ 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 speculation shocks. We do this by imposing opposite signs on the response of the spread, based on equation (8) which was derived in section 2.2. The fundamental shocks which increase oil prices have a negative effect on the futures-spot spread, whereas destabilizing speculation increases the spread after increasing the futures price of oil. Hence, we define the *destabilizing speculation shock* as a shock to the futures markets that raises the oil futures price

[6] More specifically, the main conclusions of this paper still hold when the results are generated using real crude oil prices, different maturities of the futures contracts (2-, 6- and 12-month futures in the spread) and the index of global economic activity proposed by Kilian(2009). These results are available upon request.

[7] 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.

and increases the futures-spot spread. This could for example reflect the trading behavior of index funds that enter the oil futures market to provide a hedge against inflation, irrespective of oil market fundamentals. Note that we do not restrict any of the responses in the oil spot market following a destabilizing speculation shock, as the effect of speculative trading in the oil futures market on the spot market variables is a priori unknown, and of main interest.

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 (2009a,b), we disentangle the fundamental oil supply and oil demand shocks by relying on 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 – cf. equation (5) in section 2.2.

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 recent 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.

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 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 an expected oil fundamentals shock. Rising demand for oil caused by increased substitution of coal 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 to anticipate a higher price of oil in the future. 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.[8]

Kilian and Murphy (2010), in contrast, do separately identify an expected oil fundamental shock in their SVAR model identified with sign restrictions. Their expected fundamental shock is characterized as an oil inventory demand shock, which increases oil inventories, the oil price and production, and decreases world economic activity. As mentioned before, they interpret this expected fundamentals shock as a speculation shock. However, as explained in section 2, trading activity based on revisions about expected oil fundamentals only enhances efficient price formation in the oil market. We employ a broader definition of speculation, and so we are able to assess the effects of speculative activity which is actually detrimental for the functioning of the oil futures market, i.e. all the trading activity that can not be related to (expected) fundamentals. In our framework, we consider the expected oil fundamentals shock of Kilian and Murphy (2010) as one that still reflects efficient market functioning, and is part of the more general fundamental oil-specific demand shock.

As we only identify four oil shocks using a five-variable SVAR model, a residual shock will capture all 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 negligible.

[8]That is, if we could restrict inventories to increase after this shock, we would exclude a potentially important set of oil shocks (e.g. a substitution shock) from the model and include them in the residual shock.

4 Empirical results

4.1 Effects of different types of oil shocks

Figure 1 shows the estimated 68% confidence bands of the impulse response functions to the different types of oil shocks, together with the median as a possible summary measure. The estimated responses are shown in levels up to 60 months after the shock, and the oil shocks have been normalized to contemporaneously increase the oil price by 10%.

Similar to Kilian (2009) and Peersman and Van Robays (2009a,b), we find that the effects 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, and the oil supply shock significantly 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 an 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 lower temporarily to partially address the increased demand for oil, although this increase 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 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.[9] The spread again only declines in the short-run.

Interestingly, not only the fundamental shocks, but also the speculation shock affects oil spot prices significantly. As expected, this effect is only short-lived, in contrast to the

[9] 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.

oil price responses following the fundamental shocks. The pass-through of the speculation shock in futures prices to the spot market price for oil is however incomplete, and the futures-spot spread declines permanently.[10] We do not find a significant reaction of oil production or oil inventories, nor do we find that speculation has real economic effects.[11] The insignificant 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 speculation is indeed *not* necessarily associated with a significant change in inventories, if speculation is defined as inefficient trading in the futures market.[12]

4.2 Relevance of different types of oil shocks

The impulse response analysis shows that destabilizing speculation in the futures markets can matter as it does significantly affect spot oil prices. The forecast error variance decomposition will shed some light on the overall importance of the destabilizing speculation shock 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

[10] This implies that it is necessary to include futures market variables in the model when assessing the role of speculation, since relying on a full pass-through of futures price shocks to oil spot prices via the no-arbitrage condition is empirically not correct. Therefore, the assumption made by Kilian and Murphy (2010) to not explicitly model the oil futures market when assessing the role of speculation, and only use spot oil market variables in their SVAR, is restrictive.

[11] The insignificant response of production can not be conclusive on the validity of the Hotelling principle, which agrues 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. Following our speculation shock, we look at the effect of an increase in the futures-spot spread, independent on whether the market is in contango or backwardation.

[12] In their SVAR, Kilian and Murphy (2010) limit the response of inventories following their speculation shock by restricting the magnitude of the price elasticity of oil demand, in order to be consistent with the theoretical results of Hamilton's (2009) model on speculation. This is rather counterintuitive since they actually define a speculation shock as an oil inventory shock in the spot market. By defining speculation differently, i.e. an inefficiency shock in the futures market, we do not need to impose this restriction.

and the oil futures price.[13] The variance decompositions are obtained from the posterior draw which minimizes the distance to the median responses of the posterior distribution to preserve the orthogonality between the structural shocks, see Fry and Pagan (2010).

The left-hand side of Figure 2 displays the forecast error variance decomposition of the oil spot price. It is clear that most part of the oil price fluctuations over our sample are explained by shocks to fundamentals. At short-run horizons, over 80% of the forecast error is attributable to fundamental shocks in oil demand and supply. In the long run, this even amounts to more than 95%. Not surprisingly, oil demand shocks driven by economic activity account for most part of this contribution, explaining almost 60% of the forecast error variance in the long run, which is almost three times the contribution of the oil supply shocks and about five times the one of the oil-specific demand shock. Clearly, this implies that the importance of non-fundamental speculation shocks is rather limited, although this depends somewhat on the forecast horizon considered. In the short term, destabilizing speculation shocks account for a non-negligible 18% of the forecast error decomposition. Nevertheless, Figure 2 shows that the share of speculation in explaining oil price variability declines quickly as the length of the forecast horizon grows. In the long run, this share reduces to 5% and oil prices are almost entirely driven by oil supply and demand-side fundamentals.

The right-hand side of Figure 2 shows the forecast error decomposition of the futures price. Destabilizing speculative activity plays a significantly larger role in explaining futures price movements, contributing 36% to the forecast errors at short horizons. This contribution declines at longer horizons, reaching 9% in the long run. Indeed, 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 speculation 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 speculation 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, implying that the four shocks identified in our framework capture almost the entire forecast error variability of oil spot and futures prices over our sample.

[13] The forecast error decompositions of the other variables in the SVAR model are available on request.

4.3 Explaining recent oil price fluctuations

Although the destabilizing speculation shock only explains a limited part of the overall oil price variability over our sample, speculative activity could still be important for understanding the increased volatility 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 (Figure 3). Also here, the historical decompositions are obtained from the posterior draw which minimizes the distance to the median responses of the posterior distribution, to preserve the orthogonality between the structural shocks. 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 markets gained momentum from 2000 on, we concentrate on the oil price evolution over the period 2000:01 - 2010:02.[14]

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 related to 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 2003, 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 2003 till mid 2008 is mainly caused by positive oil demand shocks driven by growing economic activity, which pushed oil prices almost 80% 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.[15] This rising demand came against the background of increasing tightness in oil supply when global

[14] 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.

[15] 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.

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 26% higher than the baseline between 2003 and mid-2008. The role of oil-specific demand shocks is rather limited over this period and in general, the oil-specific demand shock caused oil prices to be lower than the baseline forecast. Although the contribution of this shock is compatible with a variety of interpretations, one possibility is increased substitution of oil for alternative energy sources.

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 (e.g. ECB 2010). 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, he argues that speculation could have played a role as well, although fundamentals are likely to be more important. By testing this within an empirical framework, we find similar results. 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 speculation plays an important role in explaining the steep oil price run up in 2007-2008, and pushed oil prices about 12% higher than the level justified by fundamentals over the period 2007:09 - 2008:06.[16] This could indeed be associated with the relevant inflows into passive exchange-traded funds linked to oil.

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 shows 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, destabilizing speculation contributed significantly to the fall in oil prices, overshooting the decline in oil prices by almost 35 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

[16] In a different econometric framework, similar results are also found by Lombardi and Mannucci (2011).

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 speculation played a role in explaining oil price fluctuations over the last decade. Over the period 2000-2008, in which the volume of crude oil derivatives traded on NYMEX quintupled, speculative activity in the futures market has increased oil prices by about 18 percent above the efficient level justified by (current and expected) oil fundamentals. Particularly in 2007-2008, destabilizing speculation aggravated the volatility present in the oil market. However, it is clear that shocks to oil demand and supply remain the most important determinants of oil price movements.

5 Conclusions

In this paper, we analyzed the role of speculation in determining the price of oil over the past two decades, with a special focus on 2007-2009. As the activity of financial investors in oil futures markets can at the same time enhance and distort the price formation mechanism in the oil market, we separated 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 identified three types of oil 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 non-fundamental shock as a destabilizing speculation 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. In our view, defining speculation in this way 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 speculative activity that distorts efficient price formation is not desirable, we argue that also this type of destabilizing speculation is more relevant for policy makers. We disentangled the different types of oil shocks using an SVAR model identified with sign restrictions. Several interesting conclusions emerge from our analysis.

First, we find that destabilizing speculative activity in the futures market has a significant effect on the spot oil price. This implies that speculation matters, although its effect on spot oil prices is only limited and short-lived. Destabilizing speculation does not affect oil production or inventories, and fails to have any significant real effects. The pass-through of the speculation shock in the futures markets to the oil spot market appears to be incomplete as the futures-spot price permanently increases. Second, destabilizing speculation shocks do not explain much of the variability in oil prices in the long run, although they account for a non-negligible part of oil spot price variability in the short run. Third, as expected, shocks to fundamentals still matter more for understanding oil price fluctuations over our sample. Looking at specific points in time over the past decade, we find that most part of the gradual run-up in oil prices over the 2003-2008 period is driven by unexpected increases in oil demand in the wake of a growing global economy, amid increasingly tight oil supply. Stronger oil demand and tight oil supply also explain most part of the surge in oil prices between 2007 and mid-2008, and the drop in oil prices in the second half of 2008 is also mainly on the back of a strong fall in oil demand driven by the global economic downturn that followed the financial crisis. As global economic activity gradually recovered from early 2009 on, oil prices increased again due to a recovering global demand for oil. However, also speculative activity mattered over the past decade, causing oil prices to deviate significantly from the level justified by fundamentals. In particular in 2007-2008, destabilizing speculation caused oil prices to respectively over- and undershoot their fundamental values by significant amounts.

Although we propose a way to identify destabilizing speculation, and disentangle this shock from innovations in oil supply and demand, capturing all relevant financial activity in the futures markets remains a difficult task. An interesting avenue for future research is therefore to implement speculation in a fully-fledged theoretical model, in order to better understand how speculation can impact on the price of oil. Alquist and Kilian (2010) is a first step in this direction. They build a two-country, two-period general equilibrium model of the spot and futures markets for crude oil to evaluate whether oil futures are unbiased predictors of the oil price. However, they rely on the no-arbitrage condition to link the futures market with the spot market for oil, whereas this paper shows that it is useful to allow for deviations from this condition, in order to model a wider set of trading activity in the futures market and allow for incomplete pass-through from the oil futures market to the spot 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 and trends, $A(L)$ a matrix polynomial in the lag operator L and B the contemporaneous impact matrix of the vector of orthogonalized error terms ε_t. In this paper, 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 speculation 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, which is standard in the sign restriction literature, 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 speculation 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% probability range of possible impulse responses to the shocks in Figure 1, together with the median response. The forecast error variance decomposition and the historical decomposition are based on a specific draw from the posterior distribution that minimizes the distance of all the responses with regard to the median responses generated by the posterior distribution, which is consistent with the “Median target method” proposed by Fry and Pagan (2010). This is done to preserve orthogonality between the different shocks and to make sure that the responses come from the same model. The responses based on this specific draw are similar than the ones based on the median of the posterior distribution. In general, we need 255691 draws to find 1000 successful identifications, which indicates that the data is relatively in favor of the model that generates the sign restrictions.

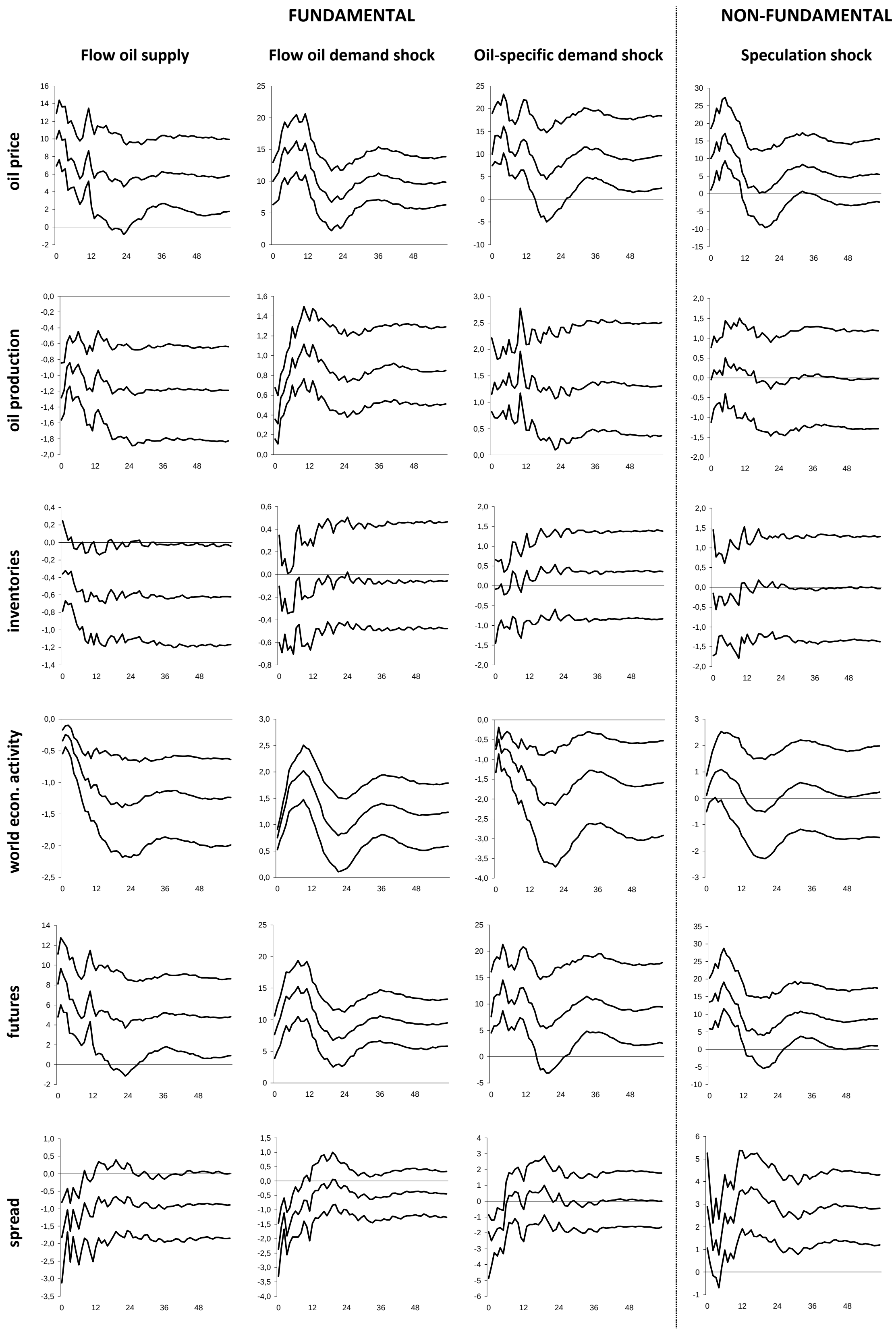

Figure 1 - Impulse response functions following different types of oil shocks

Notes: 68% probability range together with the median response of the posterior distribution, responses are in percentages and shown in levels up to 60 months after the shock. The oil shocks are normalised to increase oil prices with 10% on impact.

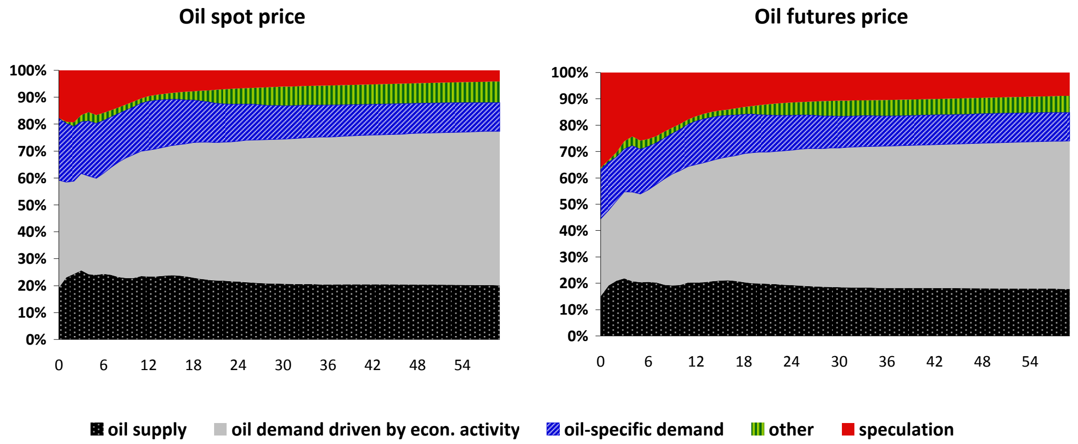

Figure 2 - Forecast error variance decomposition

Notes: Forecast error decomposition in percentages based on the posterior draw that minimizes the distance with respect to the median of the posterior of all the responses.

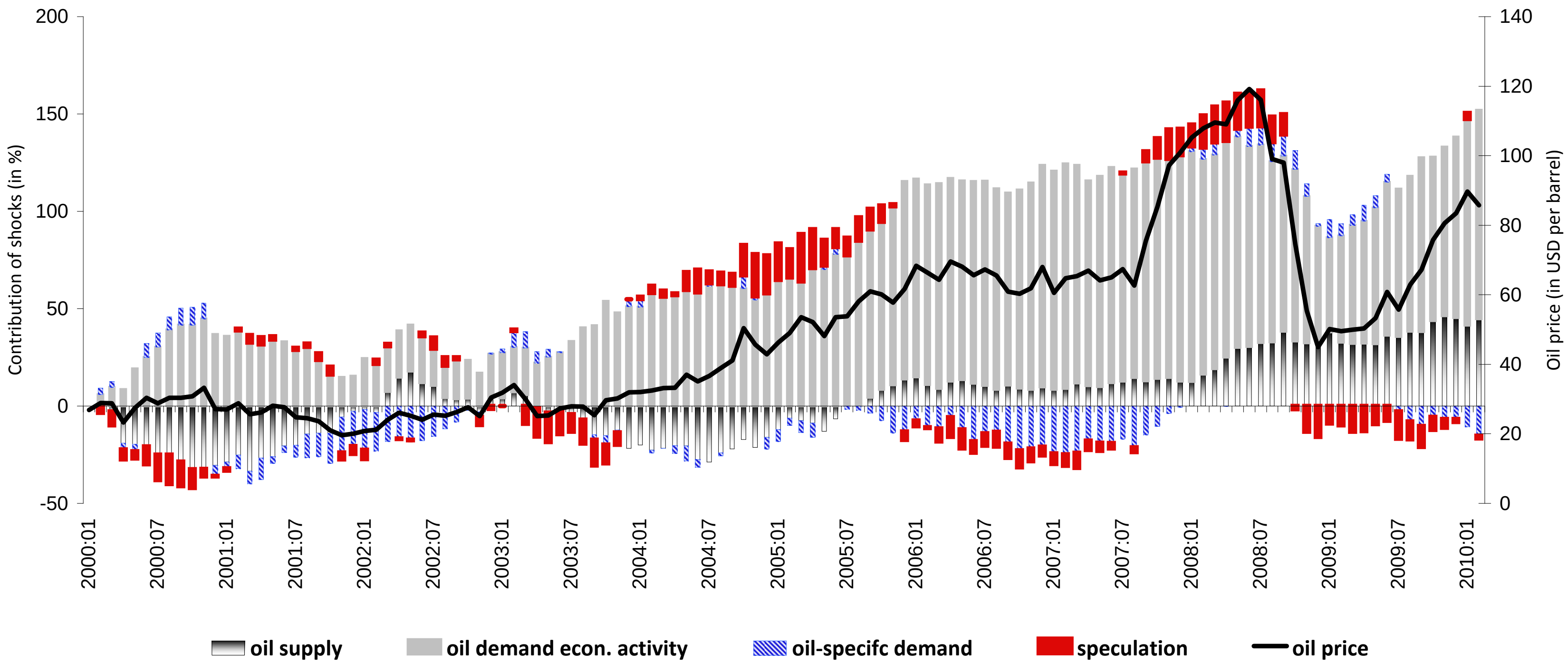

Figure 3 - Historical decomposition of the oil price

Note: historical contributions of the structural shocks are given in percentage deviations from the baseline forecast excluding the shocks. The baseline is the unconditional forecast excluding the oil shocks. The historical contributions have been normalised to zero in 2001:01 and are based on the posterior draw that minimised the distance to the median from the posterior of all the responses.