A fistful of oil barrels for a few more dollars: strategic interactions and price dynamics in the global oil market*

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Abstract

This work innovates on the existing empirical models of the oil market by distinguishing two types of supply shocks depending on the production strategy pursued by major oil producers. In particular OPEC's production policy may target a desired price or an optimal market share; in the first case it competes over quantities, in the second case over prices. We estimate a SVAR model with sign restrictions that identify the contribution of each strategy to the historical price dynamics. Compared to previous studies, in our set up supply shocks account for a greater fraction of the forecast error variance decomposition of oil prices; the contribution of unidentified shocks to price dynamcs shrinks by a third and OPEC and non OPEC suppplies are twice as elastic. Regarding the most recent shale age, we show that the shifts from price to market-share targeting and the switch back later on, explain most of the oil drop at the end of 2014 and the recovery in early 2017.

Keywords: OPEC, shale, oil, SVAR
JEL-Classification: Q41, Q43

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1 Introduction

There is a large body of literature discussing the relevance of oil prices drivers based on various models of the global oil market. The debate about which factor, supply or demand, dominates oil market dynamics is still open.

According to early literature produced in the aftermath of the two oil crises of the seventies, supply factors were the major driver of price and the macroeconomic effects of oil market shocks were unrelated to the nature of the underlying shock. This view persisted in the literature until the end of the second half of 2000, when an increasing consensus identified global demand conditions as the key factor in explaining oil price movements in certain episodes, such as in the run-up to the 2008 crisis. In particular Kilian and Murphy (2014) show that both current and forward-looking demand for oil are driven by expectations about future activity. The mainstream view sees OPEC having limited power to drive prices while demand conditions are of primarily relevance.

We contribute to this debate from a novel perspective. We show that supply shocks are of different types depending on the strategic interaction among major players in the oil market. In particular the literature has so far only considered one type of supply shock, neglecting that in oligopolistic markets major producers can decide to compete over quantities or over prices. We prove that this simplification came at the cost of underestimating the relevance of supply shocks in influencing oil price developments.

There are a number of old studies about the oil market structure (see Pyndick, 1978) and whether OPEC must be considered a cartel or rather a form of internal Stackelberg competition among its members but to the best of our knowledge none has so far quantified the effect of supply shocks when OPEC seeks to stabilize prices or regain market share on the market.

We set up a SVAR model and identify the two strategies imposing sign restriction on the impulse response function. When OPEC plays market shares targeting, it will react to innovation in non-OPEC production moving production in the same direction. On the contrary when OPEC aims at stabilizing oil prices around a target, it will try to offset the original supply shock.

We have an entire set of novel results.We find that OPEC acts strategically most of the time and that supply shocks are as relevant as demand shock in explaining historical oil price dynamics. We are able to better pin down price elasticity of demand and supply, distinguishing between OPEC and non-OPEC supply. Moreover our approach make possible to answer some relevant questions, such as: which role played OPEC, namely Saudi Arabia, in the second oil crisis in 1979 until 1985? What was the strategic reaction to the surge in shale oil production?

More generally, our framework is able to identify with more precision the turning points of prices in occasion of specific events in the oil market and reduces sensibly the residual part of the oil price dynamics due to unrestricted shocks.

The remainder of the paper is organized is as follows. In section 2, we provide a brief overview of the theoretical underpinnings that have inspired the identification strategy. Section 3 discusses the empirical strategy developed and compares it with previous models. Section 4 reports the empirical results of this set up and compare with a standard oil market model the historical decomposition of oil prices, the impulse response functions and the forecast error variance decomposition. In section 5, we derive the implied short-run price elasticities for oil demand and supply and also discuss the time-varying elasticities developments. The main conclusions of this work and the work-ahead are presented in Section 6.

2 Theoretical considerations underpinning the empirical model

The empirical studies of the oil market have rarely accounted for the effects of producers' interaction on prices and global supply , despite oil markets are known to be non competitive.[1]

Strategic interactions are overlooked in empirical models even when big producers, holding production spare capacity, are acknowledged to have an incentive to act as monopolist on the residual part of the demand curve (Caldara et. al 2017). The reason for this simplification being that supply shocks are expected to produce similar effects on prices, quantity and global activity, irrespective of their origin and composition.

This approach is instead only correct as long as major producer countries, like Saudi Arabia or the OPEC, maintain unchanged over time their production strategy; as soon as they switch from one to another, the implied equilibrium price and quantity on the market changes. Moreover whether price rather than quantity targeting is preferable depends on what strategy maximizes the OPEC's objective function. In the literature OPEC is often seen as maximising the present value of oil income future flows which depends on a number of factors, namely competitors' production capacity and efficiency, global activity, OPEC's cohesiveness, fiscal needs of oil producing countries (Behar and Ritz (2016)). Therefore the OPEC's reaction to other players' behaviour will depend on whether they pursue market share, price stabilization or any preferred combination of the two previous policies, as they are influenced differently by cyclical and structural developments in global markets as well as in the oil market.

The exact conditions that must be met in terms of market fundamentals for OPEC to prefer price(PT) versus market-share stabilization (MST) are pinned down as a function of production capacity of other producers. and production cost of the least efficient producer In particular, under market shares targeting OPEC's production is greater than under price

[1] More specifically the literature tends to define the within OPEC competition as a Stackelberg game with Saudi Arabia as leader and the rest of the member countries as followers.

stabilization (around the marginal cost of marginal producer; being the first preferable the larger and increasing is the production capacity of competitors and the higher is the marginal cost of high-cost players. Therefore switches from one to another strategy will increase the OPEC's output in order to drive prices down and induce high-cost producers to exit the market.

A subdued global oil demand facilitates this strategy because under this condition both sales and profits shrunk when prices are targeted but only sales if OPEC targets quantities. When capacity is low, revenues are maximized by price targeting.

Under market share targeting, OPEC production tends to comove with the supply of the other producers; as a result global production and prices becomes more volatile. Indeed a positive (negative) supply shock to non OPEC production is coupled with a positive (negative) supply change in OPEC production as well. Under price stabilization OPEC attempts to offset others' supply shocks by adding barrels when market lacks oil availability and subtracting in case of abundance; as quantities get stabilised also prices are less volatile.

Looking more specifically at the US shale oil boom within this conceptual framework, the OPEC's decision to defend market share and try squeezing shale producers out of the market was motivated by the dramatic expansion in production capacity of tight oil and resulted in an important increase of global production by 5 million barrels a day.

3 Empirical strategy

The empirical identification strategy exploits specific sign conditions pinned down by the theoretical framework. In that set up, OPEC production follows the same dynamics as that of non-OPEC producers, amplifying the impact of the shock on oil prices, when market share is targeted. Whereas in a price targeting strategy, OPEC tends to offset non-OPEC changes in production, attenuating oil price fluctuations. As OPEC production strategies affect oil prices and quantities, a SVAR model distinguishing between them provides us with a better understanding of factors affecting oil price dynamics.

3.1 Data

We employ monthly data of OPEC and non-OPEC production, an indicator for real economic activity, the average oil prices and US/OECD inventories as a proxy for world inventories from February 1973 to April 2017. All time series have been made stationary. OPEC and non-OPEC production, in thousands of barrel per day, are obtained from the *Monthly Energy Review* published by the US Energy Information Administration (EIA), and they are expressed in monthly percentage changes. The measure of real oil prices is derived from the average Brent crude prices, obtained from the International Financial Statistics (IFS), and deflated by the US consumer price index. Brent prices enter the model in log-levels.

As a proxy of global economic activity are used in this estimation. A monthly linear interpolation of seasonally adjusted World GDP growth is retrieved for our baseline model and expressed in monthly percent change. [2] Finally, owing to the lack of available data and following Kilian and Murphy (2014), world crude inventories are proxied by monthly changes in total US crude oil inventories, escaled by the ratio of OECD to US petroleum stocks, which are taken from the EIA [3].

3.2 A SVAR model

We use a SVAR model of the oil market to identify global and speculative demand shocks, and specifically, to distinguish between two supply shocks — a "market share targeting" and a "price targeting" supply shock — which are identified from different OPEC's reactions to non-OPEC production innovations. The model contains 24 lags and employs monthly data with the following reduced form representation:

$$Y_t = c + A(L)Y_{t-1} + \mu_t \tag{1}$$

Y_t is a vector of five endogenous variables, including (1) the monthly percentage change in OPEC crude oil production, (2) the monthly percentage change in non-OPEC crude oil production, (3) the monthly growth rate of the interpolated global GDP, (4) the log-real price of oil, (5) the monthly changes in global oil inventories. The vector c contains the intercepts, A(L) is a matrix polynomial in the lag operator and μ_t is a vector of reduced form error terms. Seasonal dummies are also included in the model to control for seasonality.

Table 1: Sign restrictions imposed

Variables	Market share targeting supply	Price targeting supply	Aggregate demand	Speculative demand
OPEC production	-	+	+	+
non-OPEC production	-	-	+	+
Real activity	-		+	-
Real price of oil	+		+	+
Inventories				+

Note: As commonly done in the literature, all responses have been normalized such as structural shocks have a positive impact on oil prices. Moreover, a fifth shock, not represented in the table, captures the unexplained part of the shocks.

[2]As a robustness check and for the sake of comparability with the main literature results, we also use Kilian's measure for global economic activity, which is based on dry cargo single voyage ocean freight rates. (See Kilian (2009)).

[3]As OECD petroleum series is only available from 1987, it is backcast until 1973 using the rate growth of US petroleum inventories, which seem to be closely correlated as suggested by Kilian and Murphy (2014).

The key identifying assumptions are sign restrictions imposed on the responses at time 0 of the five variables to the structural shocks, as well as dynamic restrictions on some of the variables (See Table 1). [4] The novelty of this set-up rests on the ability to pin down two different supply shocks, depending on OPEC's targeting "market share" or "price" targeting. In the former shock, OPEC seeks to maintain its market share by reacting to expansions (declines) in non-OPEC production by also increasing (decreasing) its supply. In this case, both productions have the same sign, leading to a decrease (increase) in oil prices and an increase (decline) in oil demand. To select only supply shocks with some persistent effect, we further impose that the oil price reaction persists for at least 12 months. On the contrary the second shock, named "price targeting supply shock", considers opposite movements in OPEC and non-OPEC production. If OPEC aims at stabilising oil prices around a target (for given global demand conditions), it must drain the eventual excess supply by reducing its own supply to support prices. In this case, no sign restrictions are imposed on price and global activity as there are two forces operating in opposite directions and the overall effect on prices and demand is ambiguous, depending on the net impact on production.

The rest of the shocks follow the recent literature and are based on the economic theory. A positive aggregate demand shock in the oil market (i.e. a shift in the demand curve) is identified by simultaneous increases in oil prices and production in both OPEC and non-OPEC countries. In the case of a speculative demand shock, market players purchase oil inventories ahead of expected future shortages in the oil market and as a result inventories and the real price of oil will go up. A higher oil price will boost oil production in OPEC and non-OPEC countries while aggregate demand will decrease.

3.3 How does this model differ from past literature?

A large part of the literature use a four-variable monthly SVAR model which identifies demand, supply and speculative shocks using sign restrictions. Our framework is based on a similar specification, but distinguish different type of supply shocks.

While the empirical literature has considered supplies homogeneously, irrespective of the origin, (Baumeister and Hamilton (2015) and Kilian and Murphy (2014), OPEC supply evolve over time depending on whether PT or MST strategies are seeked.

Against this background, it is essential to consider the strategic interactions between OPEC and non-OPEC producers. For instance, different strategies were pursued in the wake of the surge in shale oil production. In November 2014 OPEC decided to abandon its production targets in the attempt to regain market shares. However, as this strategy turned out to be more costly than expected in terms of fiscal revenues and shale oil producers were able to become more competitive in a low price environment, OPEC switched backed to a

[4] Elasticity bounds are included as a robustness check.

price stabilization strategy in order to rebalance the oil market. We propose a five-variable monthly SVAR which distinguishes between OPEC production strategies to single out their interaction and the impact on oil prices.

An additional distinctive feature of our set-up with respect to previous studies consists in employing an alternative measure of economic activity. Instead of relying on the dry cargo shipping rate index proposed by Kilian (2009) and used in Kilian and Murphy (2014), a monthly indicator of world GDP growth is preferred. While Kilian's economic activity measure, which is a deflated cost for shipping commodities, seems to have performed adequately until the onset of the financial crisis, its explanatory and predictive power have weakened since 2009. As pointed out by Baumeister and Hamilton (2017), this index shows an"erratic behaviour", particularly since the global financial crisis. This is chiefly evident during the slowdown in economic activity in early 2016, period in which the negative spike in Kilian's indicator would have predicted a more severe crisis than the global financial crisis, casting doubts about its suitability as a leading indicator. Among the major drawbacks, this indicator seems to be dominated by very few commodities (grain, oilseeds, iron ore, fertilizer and scrap metal) which might be creating an undesired volatility in some sample periods and sensitivity to the de-trending technique owing to idiosyncratic factors. Indeed, Kilian and Zhou (2017) recognize that most of the negative spike in 2016 can be explained by a decline in iron ore freight rates as in 2015 iron ore accounted for 79% of dry cargo trade. In addition to idiosyncratic factors, changes in the composition of the freight rates or the supply of bulk dry cargo carriers could also be a source of concern [5]

While monthly World GDP may not be precisely computed, especially for emerging economies, (see Kilian and Zhou (2017)),it is more appropriate to capture shifts in oil global demand as it provides a straight-forward economic interpretation, shows a strong correlation with oil prices and avoids some of the biases of Kilian's measure. At the same time the fact that it is not a leading indicator does not represent an issue for our analysis. Last, contrary to Kilian and Zhou (2017), the difference in volatility between the monthly world GDP used in our estimation and Kilian's indicator does not seem to be as relevant as suggested. (See figure 1)

As a last difference with respect to previous works, we remove elasticities bounds on oil supply and demand for a twofold reason. First there is not a consensus on what are the correct values of elasticities that should be imposed. A recent work Caldara, Cavallo, and Iacoviello (2016) has criticised their imposition and shown that small changes in the demand and supply elasticities imposed on oil structural VAR models have strong implications on the relevance of demand and supply factors in explaining oil price dynamics. For instance, a short-run elasticity on supply close to zero will imply that demand factors will play a major

[5]According to Ravazzolo and Vespignani (2015), Kilian's index could be biased due to the use of equal weighting of the different commodities and routes in his index, while one would expect some variation over time. Odom et al. (2010) also suggest that Kilian's measure can be capturing a change in the supply of shifts in some periods.

role in explaining prices. [6] Baumeister and Hamilton (2017) also raise concerns about the use of such restrictions which can lead to misleading results and propose a new methodology, using Bayesian inference which requires less restrictive identifying assumptions, consistent with the existence of uncertainty around their true values.

We are not particularly concerned about the critics of Kilian and Murphy (2012) who argue that structural models based on pure sign restrictions are weak as they include shocks that are not economically realistic since the elasticities retrieved in our work are consistent with recent results of the literature [7].

4 Long view of oil price

This section reviews and compare the empirical results of a standard model which identifies, demand, supply and precautionary demand shocks and our model which singles out two types of supply shocks in addition to demand and precautionary demand shocks. We name them respectively the 3-shocks and the 4-shocks models and compare their historical decomposition of oil prices, the impulse response functions and the forecast error variance decomposition to higlight the main contribution of the novel framework accommodating for producers strategic interactions.

4.1 Supply strategies and the past dynamic of oil prices

The historical decomposition of oil prices obtained from the 4-shocks model confirms some of the major findings of the previous literature but it also contains relevant innovations. First of all supply shocks explain a greater fraction of the oil price dynamics with respect to models neglecting strategic interaction among producers (see Kilian and Murphy (2014), Baumeister and Hamilton (2017) while demand shocks and unidentified shocks matter less.

Demand shocks continue to play a relevant role; they remain the most important factor explaining the rise of 1979 and the pre-crisis spike. Nonetheless compared to the previous models this time their contribution is smaller in both aforementioned episodes and during the premature recovery of oil quotations in the aftermath of the global crisis, when also OPEC production strategy supported prices.

Another major distinction from previous established works (Kilian and Murphy (2014), Peersman, Baumeister, et al. (2009)) is the marginal importance of speculative demand shocks in explaining oil price evolution. This result, tough, is not related to the modeling of strategic interactions among producers but it depends on the removal of restrictive boundary conditions on the supply elasticity of oil prices and, to a less extent, on the indicator of

[6] Caldara et al. (2016) analyse different historical episodes to estimate short-run supply elasticity and find an elasticity of 0.077, three times higher than the supply bound (0.0258) imposed in Kilian and Murphy (2012).

[7] Even if we do not impose tight boundaries

global activity (world gdp).Indeed both the 3 and the 4-shocks models share this same results which cannot hence depend on the distinction we draw between the two types of supply shocks.

In particular coming to the analysis of supply factors, the contribution of MST to price dynamics is very similar to standard supply shocks of earlier studies. In figure 4, panel (a) the blue solid of the 4-shocks model and the red dashed line overlap to a great extent over the entire period. The PT strategy instead identifies a new type of shock, whcih was included among the unidentified ones in old studies (see red solid line in the 4th panel of Figure 4) and that turns out tobe very relevant in a few specific historical episodes.

Specifically after the second oil crisis between 1979 until 1985, OPEC, namely Saudi Arabia, tried to counteract the drop in the oil price by restricting its production; the period is generally regarded as one of less buoyant demand, increasing non OPEC supply and declining prices. The attempt has been considered ineffective by the previous literature while our analysis suggests that it supported somewhat oil quotations. Remarkably the analysis highlights with some precision the timing of OPEC decisions. The contribution of price targeting, falls to zero in November 1985, right the month when Saudi Arabia announced to give up on its production restraints.

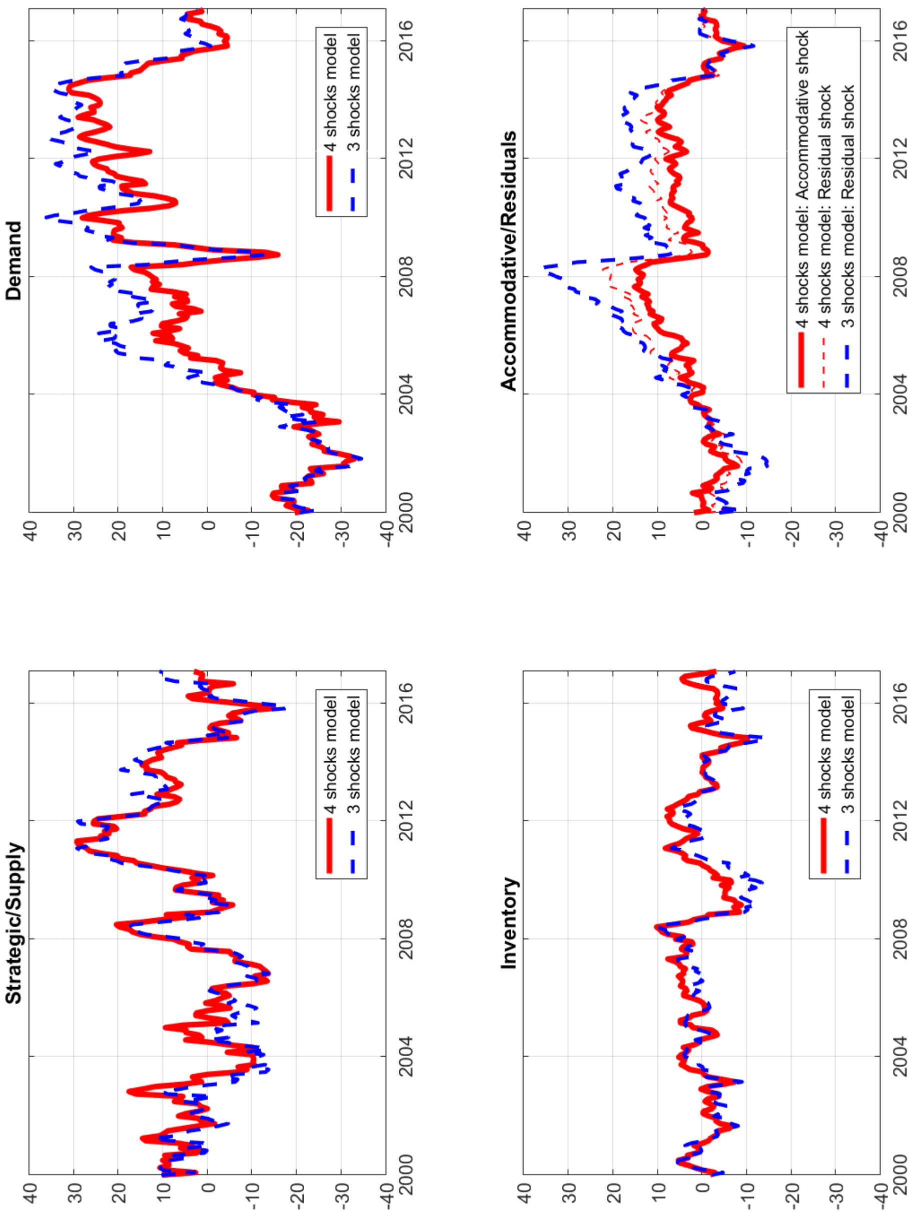
The second episode concerns the years preceding the global crisis from early 2000. While the role of the steadily rising oil demand from emerging economies was a key factor, as stressed in previous works (see Kilian (2009), our empirical findings point out that OPEC behaved so to keep the market rather tight and price elevated. A strategy confirmed by the low level of oil inventories.So to speak a strong demand was not fully accomodated by OPEC which could have further eroded its spare capacity and purposedly decided not to do.

More recently, during the shale age, demand factors were the major driver until mid-2014. Our estimations suggest that since then, oil prices have been primarily driven by supply shocks. Following the OPEC announcement that in order to regain market space, lost to shale producers, they were to abandon production targets. Most of the 57% price drop, experienced in the second half of 2014 and until early 2015, was due to supply factors (39%). In particular, targeting market share represents 25%, and an additional 7% can be attributed to the price stabilisation policy while demand factors only contributed 9%.

Convincingly a counterproof of the validity of the 4-shocks model comes from the contribution of unidentified shocks to the oil price historical evolution which gets sensibly downsized by the identification of supply shocks under PT strategy.

In chart 4 panel (d) the unidentified part is less relevant in correspondence with the strategy of PT becoming more important (especially between the end of 70‘s and mid 80‘s and during the pre-crisis quinquennium). Moreover strict comovement between supply shocks occurring during price-targeting regimes and the unrestricted part in the 3-shocks model (see blue dashed line and red solid line for the price targeting supply shock in Figure

Figure 1: The historical oil price decomposition



Notes: Last observation September 2017

4 panel 4), suggest agin the were an imparta chunk of the unexplained price dynamics.

Coming to the analysis of the past two years, the price recovery from the end of 2016 and in 2017 is consistent with the OPEC announcement (in November 2016), on the reinstatement of production quotas and a concerted production restraint. Nevertheless market share strategy also contribute to the price recovery.

4.2 Well behaved impulse response functions

The IRF analysis is consistent with the results obtained from the historical decomposition of oil prices.

In line with sign restrictions, supply shocks, occuring when market-share is targeted, reduce total production on impact, leading to persistent higher oil prices and to a fall in economic activity for over a year. Unsurprisingly, every time a supply shock occurs when a desired price is targeted, the OPEC tends to counteract it; so doing it generates an offsetting effect on the real prices of oil and the real economic activity which therefore remain overall rather unaffected.

The response of the real price of oil to a demand shock and to precautionary demand follows similar dynamics in the 3 and the 4 shocks model. As expected, it raises production on impact and oil prices in a persistent way; however in our model price reaction to speculative shocks is shorter lived and it falls back to zero after 7 instead of the 10 months of the 3-shocks model.

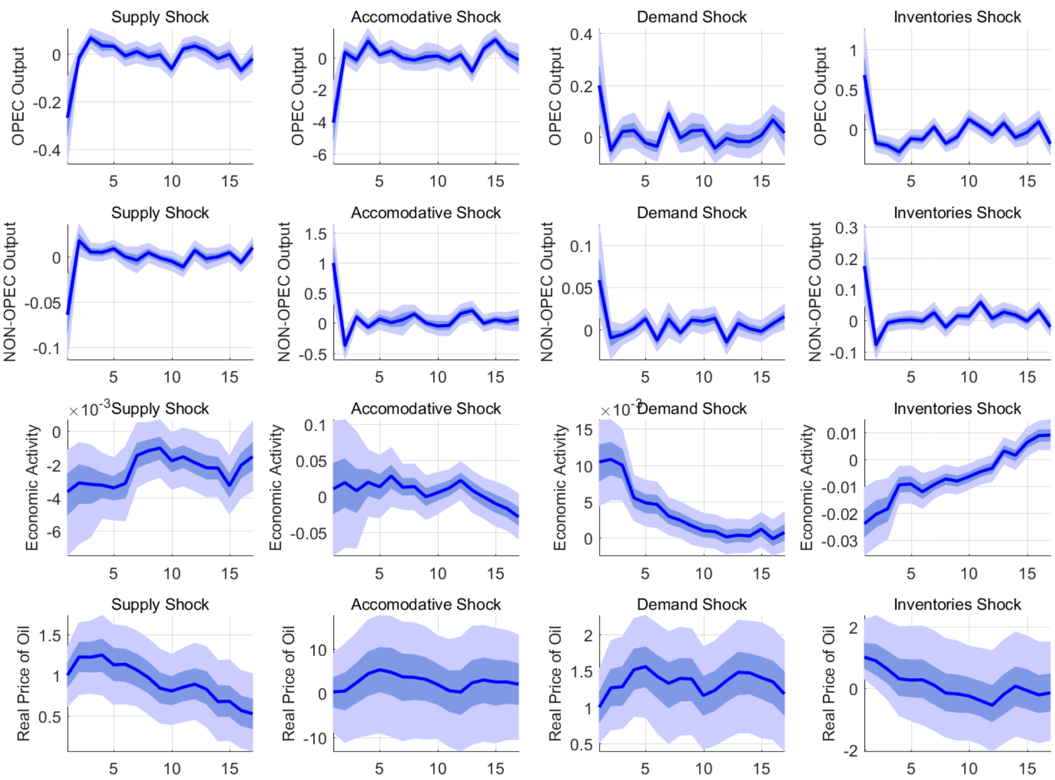
Finally, to make sure that the four shocks are correctly identified in our model, we rule out the possibility that the fifth unrestricted shock is anyhow correlated to the four identified shocks or that it affects sensibly the variables in the models. From the impulse response of the real price of oil, the global demand, the inventories and both OPEC and non-OPEC production, it is evident that the residual shocks have almost no impact on the variables considered in the model; the IRFs remain flat and insignificant at any time horizon.

4.3 FEVD what do we learn from the comparison of the 3 and 4 shocks models?

Three facts stand out when decomposing the variance of the forecast errors in the 3 and 4 shocks models.

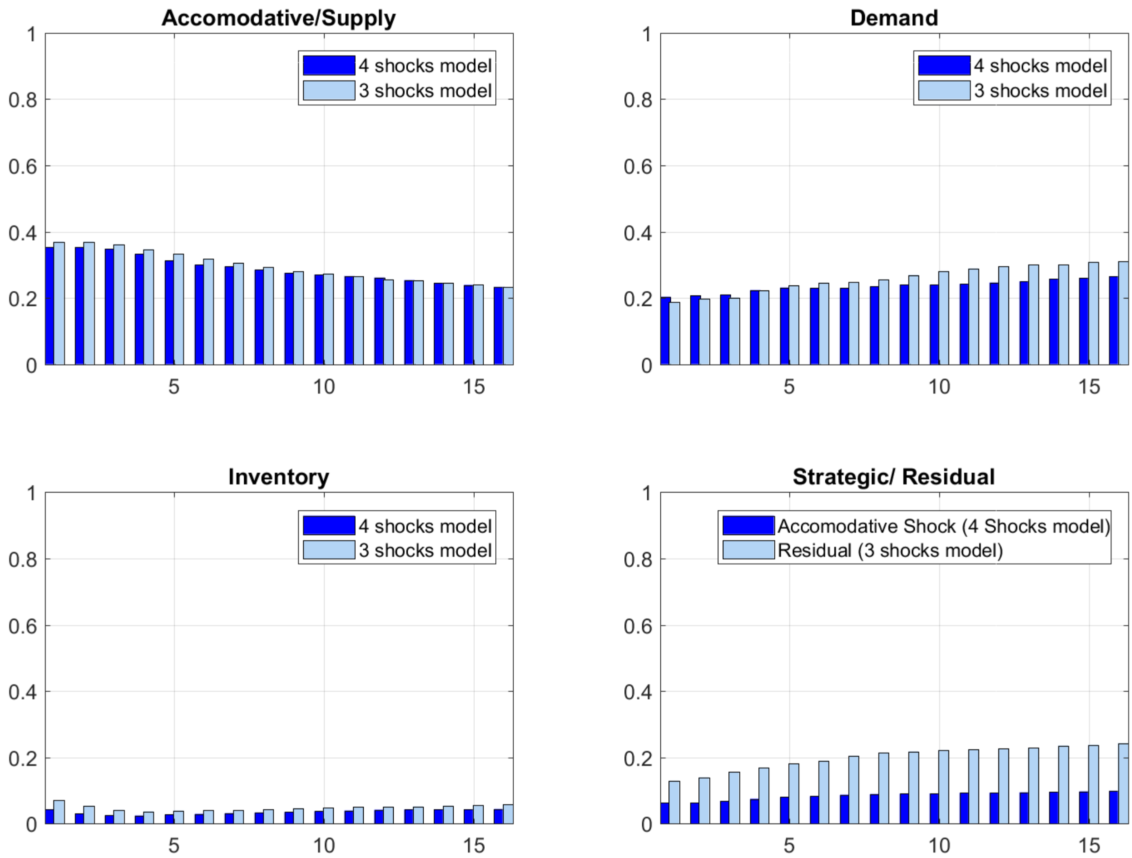
First, in the 4-shocks model the contribution to the variance of each factor is more stable at different orizons while in the 3-shocks model supply explains more at shorter horizons and less at longer horizons; the opposite being true for demand shocks. This is counterintuitive as we were exspecting supply to adjust over time so to play a greater lonr at farer horizons. In the 4-shocks this tendency gets much attenuated (see Figure 3).

Figure 2: The impulse response functions



Notes: Last observation September 2017

Figure 3: The Forecast Error Variance Decomposition of oil price: comparing the models with 3 and 4 identified shocks



Notes:Reaction to a 1 standard deviation shock

Second the relevance of demand shocks is smaller at any horizon while the sum of the variance explained by the two supply shocks under price and under market-share targeting gets larger. Precautionary demand never really played a role but it is even less relevant in the 4-shocks model.

Last but foremost, specificallyt the PT strategy explain almost an additional 10% of the FEVD which was before included in the unidentified. Indeed the part of the variance of the forecast errors explained by the residual gets smaller in the 4-shocks framework. Part of it is in fact in the extended model accounted by the supply shocks occurring during PT policies.

5 Elasticities

Based on the structural shocks identified in our specification, we estimate implied short-run price elasticities for oil demand and oil supply from the impulse response functions as the percentage change in quantities in terms of a percentage change in prices conditional to an oil demand or supply shock, respectively. In this section, we first discuss the overall implied elasticities retrieved, comparing them with the literature, and then assess the evolution of time-varying elasticities.

5.1 Short-run supply and demand elasticities

Table 2 summarizes the median short-run price elasticities derived in our model consistent with results of recent literature. Indeed, the median of the oil supply elasticity is 0.10, considerably larger than the upper bound of 0.01 assumed in Kilian and Murphy (2014), but qualitatively close to the elasticity obtained in Caldara et al. (2016) and in Baumeister and Hamilton (2017). More specifically, Baumeister and Hamilton (2017) derive a short-run oil supply elasticity of 0.15 using Bayesian inference with relaxed prior information on the size of elasticities, while Caldara et al. (2016) estimate a 0.077 short-run supply elasticity using country-level instrumental variable regressions. Larger supply elasticities can be explained by the existence of spare capacity in major oil producers and the surge in shale oil production since 2011, which is more responsive to oil prices than conventional production.

Moreover, our model enables us to distinguish between short-run price elasticities for OPEC and non-OPEC supply. Unsurprisingly, the elasticity of OPEC supply is higher than non-OPEC supply, similarly to the results obtained in Caldara et al. (2016). These authors come up with a supply elasticity of 0.22 for Saudi Arabia, 0.19 for the rest of OPEC members and -0.01 for non-OPEC countries. While our results are qualitatively similar for OPEC countries with a supply elasticity of 0.2, we also derive a positive supply elasticity for non-OPEC countries, around 0.06. OPEC adjust production in response to price changes more easily due to available spare capacity, but also to optimally decided production policies.

Table 2: Median price elasticities of crude oil supply and demand

Elasticities	Values
Price elasticity of crude oil demand	-0.281
Price elasticity of crude oil supply	
- Global	0.099
- OPEC	0.199
- non-OPEC	0.059

Note: Estimates

With regards to oil demand elasticities, the overall short-run elasticity is also closer to the estimates retrieved in recent literature. Indeed, there is an extensive literature on oil demand elasticities, with heterogeneous results as elasticities range from -0.81 for the long-run price elasticity of gasoline demand (Hausman and Newey (1995) to -0.07 of short-run oil elasticity of Caldara et al. (2016). [8] However, the recent literature challenges previous estimates and points to lower elasticities. Caldara et al. (2016) find a demand elasticity around -0.07 using data from 1985 to 2007. Gelman, Gorodnichenko, Kariv, Koustas, Shapiro, Silverman, and Tadelis (2016) retrieve a short-run elasticity for gasoline of -0.22. Therefore, a short-run elasticity around -0.285 is reasonable for an average estimation using a larger sample period, from 1973 to 2017, as there is a persistent decline in elasticities over time.

5.2 Time-varying elasticities

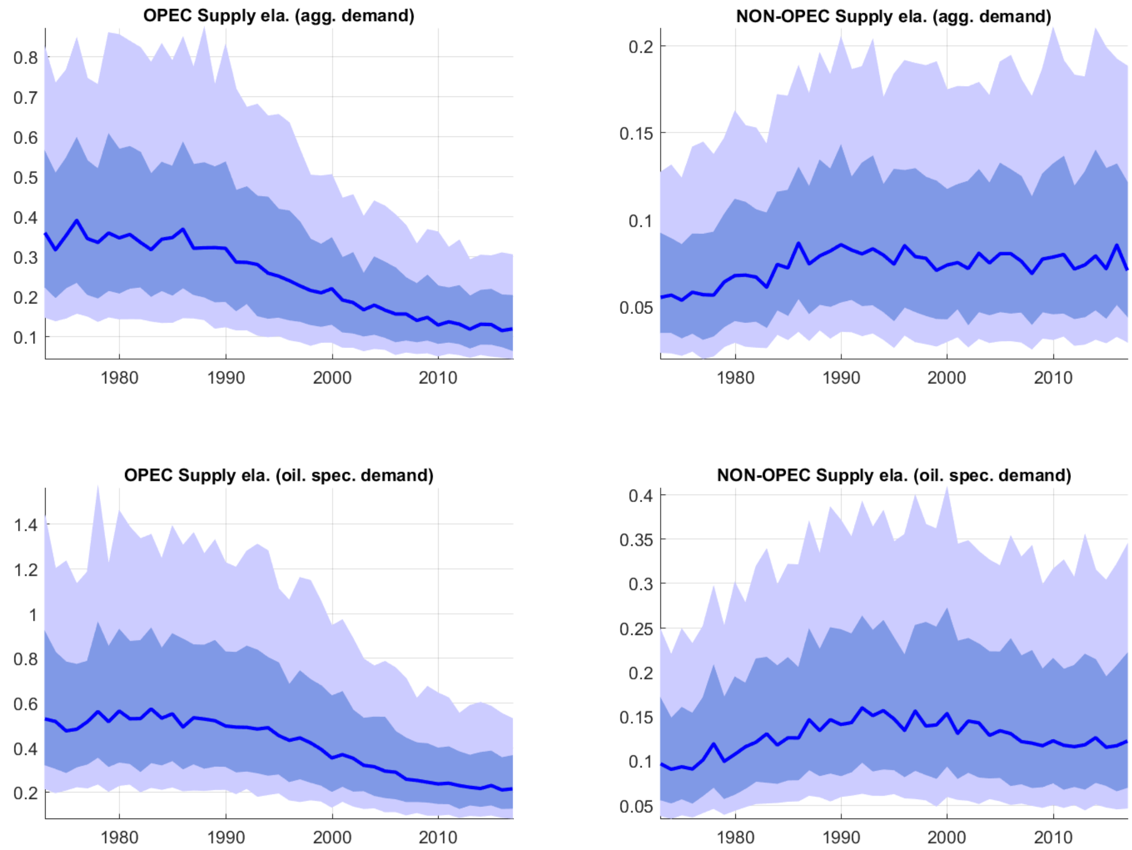
Not only is it relevant to derive overall oil demand and supply elasticities, but it is also informative to assess the evolution of short-run price elasticities. In order to so, we estimate oil supply and demand elasticities from the impulse responses at each period of time using a rolling window. (develop including the methodology used).

As two different demand shocks have been identified in our model, the global aggregate demand shock and the speculative demand shock, we can derive different OPEC and non-OPEC supply elasticities depending on the demand shock. While the dynamics of supply elasticities are quite similar, oil supply seems to be slightly more elastic in the case of a speculative shock, pointing to a different reaction depending on the source of the shock.

In addition, this time-varying supply elasticities confirm that OPEC elasticities are higher than non-OPEC elasticities for both demand shocks. Nevertheless, while OPEC supply elasticity seems to decline, for non-OPEC countries it slightly increases over time. OPEC supply elasticities are relatively more elastic in the seventies and eighties with median elasticities between 0.3 and 0.4 when computed as shifts along the aggregate demand and around 0.5 when computed from shifts along the speculative demand, while currently they are around 0.15 and 0.2, respectively. Focusing on non-OPEC time-varying supply elasticities, there is no evidence so far of a recent structural break in elasticities due to the surge in shale oil production in the US. Elasticities remained rather constant over the past two decade despite shale producers are able to stop and restart production more easily than conventional non-OPEC producers (see also forthcoming Foroni and Stracca (2018)). Two factors can be behind this result: the phenomenon is too recent for a structural break to be properly identified in a time series analysis which has to be performed including many

[8] Of course, one needs to differentiate between crude oil and gasoline elasticities and between short and long run elasticities. While it is reasonable to argue that short-run elasticity is smaller than long-run elasticities, Hamilton (2009) makes the case that crude oil demand elasticity should be around half the gasoline demand elasticity since crude oil accounts for half the retail cost of gasoline.

Figure 4: Time varying supply elasticity

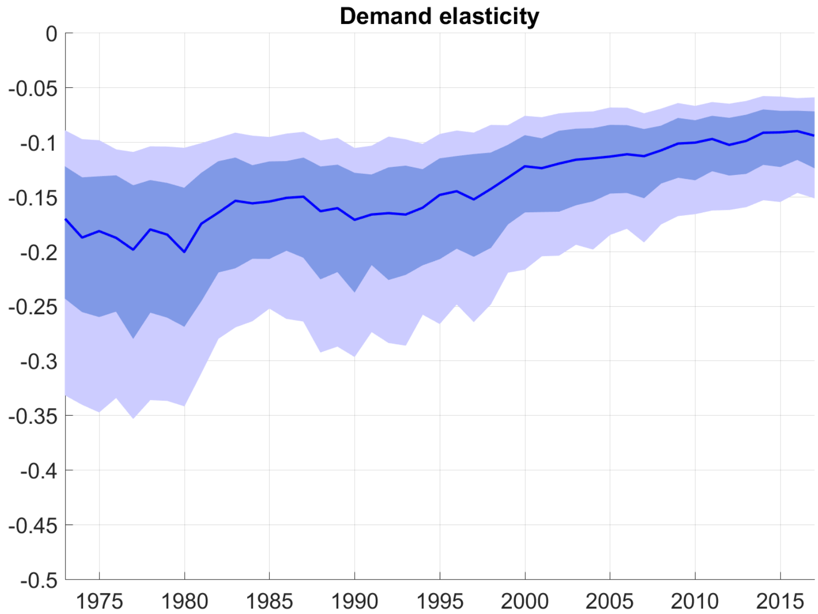


Notes: Last observation September 2017

lags (up to 24) and the share of shale oil in total production is still only around 6.5% of world oil and 11% of non-OPEC production.

Turning now to the analysis of time-varying elasticities for oil demand shown in Figure 5, median estimates have declined over time. In the seventies, oil demand median estimate was close to -0.2 until 1980, period in which they started their downward trend, in absolute value, until reaching a current level close to -0.1. The lower elasticity may result from economies having become more resilient to oil price shocks over time, chiefly owing to lower energy intensity. Its decline by a third since the early nineties is a consequence of the improved energy efficiency and the declining share of the energy intensive manufacture in global production. A similar pattern is also shown in Baumeister and Peersman (2013). However, our estimates display a smaller volatility and their magnitudes are considerably smaller in the seventies and early eighties.

Figure 5: Time varying overall demand elasticity



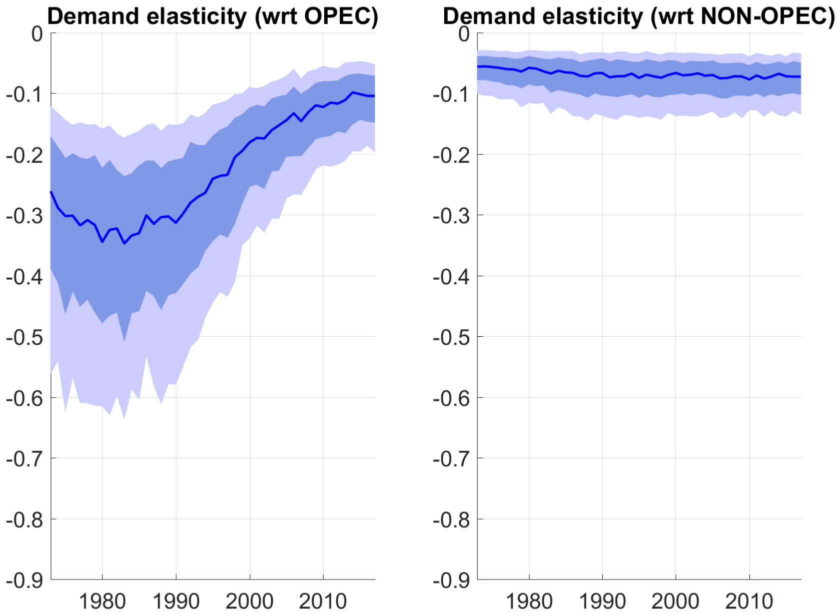
Notes: Last observation September 2017

Surprisingly, demand elasticity reacts differently depending on the source of the supply shock as observed in Figure 6. Indeed, median estimates of short-run oil demand shocks are larger in absolute value when the reaction to price changes are computed along the OPEC supply curve than when computed along the non OPEC supply curve. This is so because OPEC supply changes result from strategic actions or geopolitical tensions and tend to be persistent. On the contrary, non OPEC shocks are generally outages which tend to be reabsorbed within a short time. In the former the price shock is expected to be persistent while in the latter it rapidly revert to the original level. This difference is particularly large in the first part of the sample period and then waters down over time.

6 Conclusions

Our analysis takes into consideration, more seriously than previous studies, the oligopolistic structure of the oil market by accounting for strategic interplay among producers. We aim at showing how this feature affects our understanding of the oil market. To this scope we focus on OPEC production policies as a result of its interactions with other producers and show their influence on oil prices and market features. In particular by identifying the periods during which OPEC pursued price versus market-share targeting, we improve on the ability of the existing literature to explain historical oil price movements and to account

Figure 6: Time varying demand elasticity



Notes: Last observation September 2017

for the forecast error variance decomposition. As a complementary result, we are able to compute more realistic price elasticity of both supply and demand than what is generally assumed in previous works. We reach some new conclusions from it.

1. There is no clear dominance of demand and supply factors, each one play a relevant role in explaining oil price dynamics, depending on the historical period analysed. In particular, global demand shocks remain the major driver in the late 1970s and early 1980s but our model downplays their role in the last commodities super-cycle (from 2004 onward).

2. OPEC policies have contributed to maintain oil price elevated in certain specific episodes and to depress them in others. Our framework identifies specific episodes when OPEC acted to tighten up the market or kept it tight. Precisely the model highlights the contribution of OPEC's policy (namely Saudi Arabia) in preventing quotations from dropping further in the period between 1979 and 1985, generally characterised by less buoyant demand, increasing non-OPEC supply and declining prices. OPEC pursued a price-targeting policy also in the decade 2004-2014; before the crisis it actively worked to maintain a relatively tight market balance and elevated quotations, after the crisis it acted to push up quotations ahead of the economic recovery. At the same time two thirds of the price drop between the end of 2014 and early 2015 is attributed to the OPEC's market-share targeting while the opposite

move, tightening up global supply to facilitate the reabsorption of oil inventories overhung, contributed to the recovery since the end of 2016.

3. Precautionary demand loses any relevance when boundaries, commonly imposed by the literature, on the supply elasticity are removed.

4. The price elasticity of the OPEC supply curve is greater than the price elasticity of the non OPEC supply curve as the first can manage production also in the short run through spare capacity adjustments. The overall elasticity is above the value obtained or imposed in models which do not distinguish between the two type of supplies.

5. Similarly we distinguish two different price elasticities of demand depending on whether we compute them along the OPEC or non OPEC supply. Global demand is more elastic when the sensitivity is estimated along the OPEC supply curve. Our reading relates this result to the persistence of OPEC versus non OPEC production shocks. As the former results from optimal production decisions or geopolitical tensions they tend to last longer than those generally originated by outages which get reabsorbed shortly after. In both cases the demand sensitivity to price changes got squeezed over time as energy intensity declined steadily starting from the 8́0s and global economy become more resilient to oil shocks.

More generally, our framework has two major advantages over standard models of the oil market which do not distinguish OPEC production policies: it is able to identify with more precision the turning points of prices in occasion of specific events in the oil market and it reduces sensibly the unexplained part of oil price dynamics represented by the residual shocks.

The differences we identified in supply and demand elasticities as well as the fact that oil price volatility may turn out to be larger under MST and lower under PT make this framework particularly appealing to analyse the impact of each type of supply strategy on consumer price dynamics. This is left to be developed in future work jointly with a torough theoretical model underpinning the sign restrictions we imposed to identify the 4 shocks in our new SVAR model.

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