Oil Price Elasticities and Oil Price Fluctuations*

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Abstract

Studies that identify oil shocks using structural vector autoregressive (SVAR) models have reached different conclusions on the relative importance of supply and demand factors in explaining oil market fluctuations. We show that this disagreement is due to different assumptions on the oil supply and demand elasticities that determine the identification of the oil shocks. We then provide new estimates of oil-market elasticities by combining a narrative analysis of episodes of large drops in oil production with country-level instrumental variable regressions. When the estimated elasticities are embedded into a SVAR model, supply and demand shocks play an equally important role in accounting for fluctuations in oil prices and oil quantities.

KEYWORDS: Oil Market; Oil Elasticity; Vector Autoregressions; Narrative Analysis; Instrumental Variables.


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1 Introduction

Academics, practitioners, and policymakers attribute swings in the price of oil to a variety of forces, such as changes in global demand, disruptions in supply, and precautionary motives. However, the relative importance of these forces remains highly debated. In their chapter in the Handbook of Macroeconomics, Stock and Watson (2016) summarize the academic debate by comparing an early literature that finds an important role for oil supply shocks in driving oil market fluctuations to a more recent literature that finds that most movements in oil prices are demand-driven.

In this paper, we assess the relative importance of supply and demand factors in explaining oil market fluctuations, and find that supply and demand shocks are equally important in accounting for fluctuations in oil prices and oil quantities. We reach this conclusion in two steps. First, we combine narrative analysis with a panel of observations on country-specific oil production and consumption to estimate oil supply and demand elasticities. Second, we embed these elasticities in a structural vector autoregressive (SVAR) model to identify the oil supply and demand equations and, consequently, the associated oil supply and oil demand shocks.

Our starting point is to show how the cross-equation restrictions that are inherent in standard VAR models of the oil market impose an inverse, nonlinear relation between the short-run price elasticities of oil supply and demand. This relation implies that seemingly plausible restrictions on the oil supply elasticity may map onto implausible values of the oil demand elasticity, and vice versa. For instance, if one imposes a short-run oil supply elasticity of zero, a common value in the literature, the resulting oil demand elasticity is $-1$, a value which is in the high end of the empirical estimates.\textsuperscript{1}

Similarly, if one imposes an oil demand elasticity of $-0.05$, a value in the ballpark of the empirical estimates, the resulting supply elasticity is large, close to 0.5.

We next argue that the selection of the elasticities is essential for understanding sources and consequences of oil market fluctuations, and that seemingly small changes in these elasticities have large effects on the relative importance of demand and supply forces. In particular, with a configuration of the oil market characterized by a zero supply elasticity, all movements in oil prices are attributed

\textsuperscript{1}See, for instance, Kilian (2009) and Stock and Watson (2016) for examples of studies that set the supply elasticity to zero. See Hamilton (2009) for a survey of the estimates of the short-run price elasticity of demand for crude oil: the average estimate of the demand elasticity is $-0.06$. 
Figure 1: Quantities and Prices in the Oil Market

Figure 1 shows a scatter plot between monthly surprises in oil prices and global oil production implied by simple univariate AR(1) regressions. The dots show that oil prices and global oil production are uncorrelated. This lack of correlation could be the outcome of very different oil market configurations. On one hand, as shown by the dashed lines in Figure 1, the supply curve could be inelastic, while the demand curve could be very elastic. As a result, fluctuations in oil prices and oil production would be disconnected, with prices driven uniquely by demand shocks, and production driven uniquely by oil-specific demand shocks. By contrast, setting the supply elasticity to 0.1 implies that oil supply and oil demand shocks are equally important drivers of oil price fluctuations.
supply shocks. On the other hand, a market characterized by a very elastic oil supply curve and an inelastic demand curve—the dotted lines in Figure 1—would also lead to a disconnect of movements in oil prices and oil production. In between these two extremes lies an oil market with a downward-sloping demand curve and an upward-sloping supply curve—the solid lines in Figure 1—which would imply that demand and supply shocks jointly affect oil prices and production. These market configurations, which we picked among many for illustrative purposes, are equally consistent with the data but have different implications for the causes and the consequences of oil price fluctuations.

In order to estimate oil supply and demand elasticities, we combine narrative analysis with instrumental-variable regressions for a large panel of countries. For each country, we instrument the price of oil with large, exogenous declines in oil production occurring in other countries. Using this approach, we find a supply elasticity of about 0.08, and a demand elasticity of about −0.07. We use these estimated elasticities as external information to identify the structural shocks in our SVAR model. In particular, we propose an identification scheme that minimizes the distance between the elasticities consistent with the cross-equation restrictions of the VAR, and the elasticities derived using external information. In doing so, we derive SVAR-consistent elasticities of 0.11 for supply, and of −0.13 for demand.

Even with this identification strategy in hand, an additional challenge is to disentangle demand shocks that are specific to the oil market from demand shocks that originate from changes in global economic activity. To this end, we use three indicators of global activity that provide a broad characterization of the global demand for oil. We construct two separate indicators based on industrial production, one for emerging economies, and another for advanced economies, dating back to the mid 1980s. These indicators allow us to measure the distinct consequences of oil shocks on advanced versus emerging economies in a parsimonious model. Our third indicator is an index of industrial metal prices, which are often viewed by policymakers and practitioners as leading indicators of swings in economic activity and global risk sentiment.\(^2\)

\(^2\)The use of IP indicators for advanced and emerging countries to measure global activity hews closely to the work of Baumeister and Hamilton (2015) and Aastveit et al. (2015). The use of metal prices follows the lead of Barsky and Kilian (2001), who propose the use of an index of industrial commodity prices—excluding oil—to identify broad-based shifts in global demand, as well as the more recent work of Arezki and Blanchard (2014), who exploit the idea that metal prices typically react to global activity even more than oil prices. Other studies that find a meaningful link between cyclical fluctuations in global economic activity and movements in metal prices include Pindyck and Rotemberg (1990), Labys et al. (1999), Cuddington and Jerrett (2008), Lombardi et al. (2012), Issler et al. (2014),
Our analysis delivers the following results. First, oil supply shocks are the main driving force of oil market movements, accounting for about 35 percent of the volatility of oil prices and oil production. Shocks to global economic conditions also play an important role, explaining 35 percent of the volatility of oil prices, and about 25 percent of the volatility of oil production. Second, a drop in oil prices driven by either oil demand or supply shocks depresses economic activity in emerging economies. A drop in oil prices boosts economic activity in advanced economies only if it is supply-driven. Given the historical realization of these oil shocks, these findings help rationalize the muted effects of changes in oil prices on global economic activity.

Our contribution to the literature is twofold. First, we provide a transparent analysis that highlights the importance for inference of selecting the restrictions on the oil supply and demand elasticities in a VAR framework. We stress how in a VAR model there is a tight equivalence between setting a specific value for the oil supply elasticity, on the one hand, and imposing a particular value for the oil demand elasticity on the other. Second, we jointly select oil supply and demand elasticities in a manner that combines external information from country-specific episodes of oil shocks with the cross-equations restrictions that are inherent in the VAR.

Our paper is related to Kilian and Murphy (2012), Lippi and Nobili (2012), and Baumeister and Hamilton (2015), who embed prior distributions for the elasticities in SVAR models of the oil market in order to identify shocks to oil supply and demand. Compared with these studies, we show that small differences in the elasticities have a substantial effect on inference, in particular on the decomposition of oil price movements. The use of narrative analysis on oil shocks builds off the work of Hamilton (2003) and Kilian (2008), who use country-specific episodes of exogenous disruptions in oil production to estimate the macroeconomic effects of oil supply shocks. Unlike these earlier studies, we use country-specific oil supply shocks as instruments to identify both supply and demand curves in the oil market. Our estimate of the global oil supply elasticity is within the range of estimates available in the literature, in line with the estimates by Baumeister and Hamilton (2015), but nearly three times as large as Kilian and Murphy (2012). Importantly, we find larger supply elasticities for OPEC members—especially for Saudi Arabia—than for non-OPEC producers. This finding reinforces the plausibility of our estimation approach, as OPEC producers are the group

Delle Chiaie et al. (2015), and Stuermer (2016).
with the largest volume of oil capacity that can be used to offset disruptions in oil supply within a short period of time. Similarly, our estimates of the oil demand elasticity are in line with existing empirical studies. Finally, our approach of combining country-specific data on oil production with an aggregate VAR echoes the approach of the global VAR (GVAR) literature pioneered by Dees et al. (2007), and Mohaddes and Pesaran (2016).

The reminder of the paper is organized as follows. In Section 2, we discuss the econometric framework and the identification strategy. In Section 3, we derive the target elasticities. In Section 4, we embed the target elasticities in a SVAR model, and assess the role of supply and demand forces in explaining oil market fluctuations. In Section 5, we show that our results continue to hold in a model that explicitly considers the role of global oil inventories. Section 6 concludes.

2 Identifying Oil Market and Global Activity Shocks

2.1 Model Overview

The structure describing the oil market and its relationship with the global economy is given by the following SVAR model:

\[ AX_t = \sum_{j=1}^{p} \alpha_j X_{t-j} + u_t, \]

where \( X \) is a vector of oil–market and macroeconomic variables, \( u_t \) is the vector of structural shocks, \( p \) is the lag length, and \( A \) and \( \alpha_j \) for \( j = 1, \ldots, p \) are matrices of structural parameters. The vector \( u_t \) is assumed to have a Gaussian distribution with zero mean and variance-covariance matrix \( E[u_t u_t'] = \Sigma_u \). Without loss of generality, we normalize the entries on the main diagonal of \( A \) to 1 and we assume that \( \Sigma_u \) is a diagonal matrix. The reduced-form representation for \( X_t \) is the following:

\[ X_t = \sum_{j=1}^{p} \gamma_j X_{t-j} + \varepsilon_t. \]

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3See Hamilton (2009) and Baumeister and Hamilton (2015) for a summary of the existing empirical evidence on the short-run price elasticity of crude oil demand. Gelman et al. (2016), using daily transaction-level data for a large panel of individual, find a demand elasticity of gasoline close to \(-0.2\). Coglianese et al. (2017) estimate an elasticity of gasoline demand of \(-0.37\) that is not statistically significant. As discussed in Hamilton (2009), since crude oil represents about half of the retail cost of gasoline, the price elasticity of demand for crude oil should be about half of that for retail gasoline.
where the reduced-form residuals $\varepsilon_t$ are related to the structural shocks $u_t$ as follows:

$$
\varepsilon_t = B u_t, \\
\Sigma_\varepsilon = B \Sigma_u B',
$$

where $B = A^{-1}$, so that $u_t$ can be alternatively expressed as $u_t = A \varepsilon_t$. Estimation of the reduced-form VAR allows to obtain a consistent estimate of the $n (n + 1) / 2$ distinct entries of $E [\varepsilon_t \varepsilon_t'] = \Sigma_\varepsilon$.

To recover the $n^2$ unknown entries of $B$ and $\Sigma_u$, we make $(n - 1)n/2$ identifying assumptions on the parameters of matrix $A$.

To discuss our identification strategy, it is useful to distinguish between an oil–market block and a global–activity block, which we jointly characterize using five endogenous variables. The oil block includes (1) the log of global crude oil production, $q_t$; and (2) the log of oil prices, $p_t$. The global activity block consists of: (3) the log of advanced economies IP, $y_{a_t}$; (4) the log of emerging economies IP, $y_{e_t}$; and (5) the log of the IMF metal price index, $m_t$. All series are linearly detrended. Oil prices and metal prices are expressed in real terms.\(^4\)

The model, which includes a constant and 24 lags of the endogenous variables, is estimated on monthly data from 1985 to 2015 employing Bayesian techniques.\(^5\) We start the sample in the mid-1980s as it coincides with the decision by the Organization of Petroleum Exporting Countries (OPEC) to abandon an administered official selling price and to adopt a market–based system. In addition, Baumeister and Peersman (2013a,b) show that large changes in the time-series properties of oil–market variables took place around the mid-1980s.

In the remainder of this section, we compare results under our baseline model specification to those obtained estimating the VAR model in Kilian (2009). The two major differences in the specification of the reduced-form models are in the choice of sample—which goes from 1973 to 2007 in Kilian (2009)—and in the choice of global activity indicators: Kilian (2009) uses an indicator based on dry

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\(^4\) Appendix A describes in detail the data and the construction of the IP indexes. Our indexes include economies that account for 90 percent of global GDP, 55 percent of global oil production—as many oil producers do not have reliable IP data—and 80 percent of global oil consumption.

\(^5\) We impose a Minnesota prior on the reduced-form VAR parameters by using dummy observations (Del Negro and Schorfheide, 2011). The vector of hyper-parameters of the prior is $\lambda = [1, 2, 1, 1, 1]$. We use the first two years of data as a training sample for the Minnesota prior. Results are based on 10,000 draws from the posterior distribution of the structural parameters, with the first 2,000 draws used as a burn-in period.
cargo ocean freight rates, designed to capture shifts in the demand for industrial commodities and, similarly to the metal price index, to capture expected changes in global activity.

2.2 A Structural Model of the Oil Market and the Global Economy

The following five equations describe the joint modeling of the oil–market and the global–activity blocks, and summarize the restrictions we impose on the parameters in matrix $A$:

$$q_t = \eta_S p_t + u_{S,t}, \quad (5)$$
$$q_t = \eta_A y_{A,t} + \eta_E y_{E,t} + \eta_D p_t + u_{D,t}, \quad (6)$$
$$y_{A,t} = \nu Q q_t + u_{A,t}, \quad (7)$$
$$y_{E,t} = \mu Q q_t + \mu_A y_{A,t} + u_{E,t}, \quad (8)$$
$$m_t = \psi Q q_t + \psi_A y_{A,t} + \psi_E y_{E,t} + \psi_P p_t + u_{M,t}. \quad (9)$$

Equations (5) and (6) describe the oil market block. Equation (5) describes the oil supply schedule. We assume that oil production $q_t$ responds contemporaneously only to changes in oil prices. The parameter $\eta_S$ denotes the short-run price elasticity of supply. The supply shock $u_{S,t}$ captures disturbances to oil supply due to, for instance, geopolitical events, natural disasters, and technological innovations in oil extraction. Equation (6) describes the oil demand schedule: oil demand is allowed to respond contemporaneously to the level of economic activity in advanced and emerging economies, $y_{A,t}$ and $y_{E,t}$, and to oil prices. The parameter $\eta_D$ denotes the short-run price elasticity of demand, and is defined as the change in desired demand $q_t$ for a given change in oil prices $p_t$, holding activity in advanced and emerging economies constant. The oil-specific demand shock $u_{D,t}$ captures changes in oil prices due to, for instance, speculation and shifts in the precautionary demand for oil caused by oil price volatility. $^6$

Equations (7) to (9) describe the global activity block. Equation (7) determines activity in advanced economies. We assume that $y_{A,t}$ responds within the period only to oil production. Equation (8) determines activity in emerging economies, $y_{E,t}$. We assume that $y_{E,t}$ responds within the

$^6$See for instance Beidas-Strom and Pescatori (2014) and Juvenal and Petrella (2015), who examine the role of speculation in driving oil price fluctuations.
period to $y_a_t$ and to oil production. Our assumption that $y_e_t$ reacts contemporaneously to $y_a_t$ is meant to capture the idea that exports to advanced economies are an important component of aggregate demand in emerging economies. Our model assumes that the oil market has a contemporaneous and direct effect on both $y_a_t$ and $y_e_t$ only through changes in $q_t$, as oil is an input in the production of manufactured goods. However, changes in oil prices have an indirect contemporaneous effect on real activity by inducing changes in oil production. Equation (9) determines metal prices, which are allowed to respond contemporaneously to all variables in the system. The shock $u_{M,t}$ mainly captures news about global activity.\(^7\)

The use of zero restrictions to model the interaction between the oil market and global activity is consistent with the assumptions in Kilian (2009), who also assumes that oil supply does not respond to shocks to global activity, while oil demand does. The key difference between Kilian’s (2009) identification strategy and ours lies in the choice of the oil supply and demand elasticities $\eta_S$ and $\eta_D$. Kilian (2009) assumes that the oil supply elasticity is zero. By contrast, we generalize his framework to encompass any possible value for the supply elasticity, and by using three indicators of global activity instead of one.

### 2.3 Identification of The Oil Market Block

In this subsection, we show how seemingly plausible restrictions on the oil supply elasticity $\eta_S$ may map onto implausible values of the oil demand elasticity $\eta_D$, and vice versa.

Figure 2 illustrates this result. The blue circle indicates a pair of elasticities, denoted by $(\eta^*_S, \eta^*_D)$, that represent an oil market configuration featuring a moderately inelastic supply schedule ($\eta_S = 0.077$) and an inelastic demand schedule ($\eta_D = -0.074$). These oil price elasticities are based on the country-level, instrumental-variable panel regressions presented in Section 3. As discussed in the introduction, we refer to these elasticities as external information, as they are derived from data and identification assumptions that are external to the SVAR model.\(^8\)

The black line in Figure 2 depicts all combinations of $\eta_S$ and $\eta_D$ that are consistent with the

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\(^7\)We estimated a model that imposes the alternative ordering between $p$ and $m$ and found very similar results to those reported below.

\(^8\)Section 3 describes the uncertainty around the point estimates, which is included in our identification strategy as described at the end of this section.
Figure 2: Oil Demand and Supply Elasticities Implied by the VAR Model: Baseline VAR Specification

(Note: The solid line plots the relationship between the price elasticity of oil supply and oil demand implied by the baseline SVAR model described in Section 2. The blue circle corresponds to the elasticities estimated in Section 3 ($\eta_S = 0.077, \eta_D = -0.074$). The green square corresponds to the elasticities selected by our identification scheme ($\eta_S = 0.11, \eta_D = -0.13$). See Section 2 for additional information.

Data—as summarized by setting $\Sigma_\epsilon$ at its OLS estimate—and with the zero restrictions described above. This set of admissible elasticities describes very different oil market configurations. For instance, at one extreme lies an oil market characterized by an inelastic supply curve—corresponding to $\eta_S = 0$—and an elastic demand curve—corresponding to $\eta_D \simeq -1$. At another extreme lies a market characterized by an elastic supply curve ($\eta_S = 0.4$) and an inelastic demand curve ($\eta_D \simeq -0.05$). More generally, all oil market configurations with a downward-sloping demand curve and an upward-sloping supply curve lying between these two extremes are admissible.

Importantly, Figure 2 shows that the oil market configuration that is implied by the external information is not admissible with the VAR model. Taken at face value, the external information could be used to dismiss the VAR model on the ground that restricting one of the elasticities to a plausible value leads to an implausible value for the other elasticity. Alternatively, the restrictions
implied by the VAR model could be used to dismiss the external information on one of the two elasticities. Yet, assessing the reliability of the external information relative to the VAR model is often hard, as the methodologies involved have relative benefits and shortcomings. For this reason, we propose to strike a balance between the external information and the VAR model by proposing the following approach.

Specifically, our identification strategy selects a pair of admissible elasticities $\eta_S$ and $\eta_D$ by minimizing the Euclidean distance between the VAR-admissible elasticities and target elasticities $(\eta^*_S, \eta^*_D)$ that summarize the external information. Consider $\eta_D$ as a function of $\eta_S$ and of the variance-covariance matrix of the estimated reduced-form residuals, $\eta_D (\eta_S; \Sigma_\varepsilon)$. Our identification strategy solves the following problem:

$$
\min_{\eta_S} \begin{bmatrix} \eta_S - \eta^*_S \\ \eta_D (\eta_S; \Sigma_\varepsilon) - \eta^*_D \end{bmatrix} V^{-1} \begin{bmatrix} \eta_S - \eta^*_S \\ \eta_D (\eta_S; \Sigma_\varepsilon) - \eta^*_D \end{bmatrix},
$$

where $\eta^*_S$ and $\eta^*_D$ are the target values for the supply and demand elasticities, respectively, and $V$ is a diagonal matrix of weights. We summarize the external information into a mean component, the targets $\eta^*_S$ and $\eta^*_D$, and into a covariance component, which we use to calibrate the weights $V$. If the external information is perfectly consistent with the VAR, $\eta^*_S$ and $\eta^*_D$ are on the curve plotted in Figure 2 and the distance between the VAR-implied elasticities and the targets is zero. By contrast, if the external information is not consistent with the VAR, $\eta^*_S$ and $\eta^*_D$ are not on the curve and the identification selects the pair of elasticities on the curve that are as close as possible to the targets, assigning a larger weight to the elasticity that is more precisely estimated. In our application, the identification selects $\eta_S = 0.11$ and $\eta_D = -0.13$, denoted by the green square in Figure 2.

Figure A.4 in the Appendix compares the implications of our VAR for the admissible demand and supply elasticities with those entailed by the VAR model of Kilian (2009). When one uses Kilian’s variables and sample period—from 1973 through 2007—any given supply elasticity implies an admissible demand elasticity which is larger, in absolute value, than in our specification. For instance, given a supply elasticity equal to zero, our VAR estimates are consistent with a demand

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9We parameterized the problem by expressing $\eta_D$ as a function of $\eta_S$ so that matrix $A$ satisfies the necessary and sufficient conditions for identification of Rubio-Ramírez et al. (2010). Thus, the structural parameters $(\nu_Q, \mu_Q, \mu_A, \eta_A, \eta_E, \eta_D, \psi_Q, \psi_A, \psi_E, \psi_P, \Sigma_u)$ are uniquely identified given information from $\Sigma_\varepsilon$. 
elasticity of about $-1$, while Kilian’s VAR is consistent with a demand elasticity of about $-3.5$. This difference is by and large due to the different sample period: in fact, when Kilian’s model is estimated on data from 1985 to 2007, the relationship between elasticities—denoted by the green dashed curve in Figure A.4—is nearly identical to our baseline model.

In sum, standard VAR models of the oil market face an important trade–off. The conventional wisdom is that both demand and supply elasticities are very small, perhaps very close to zero in a period as short as one month. However, this view is at odds with the data, at least when the data are seen through the lens of a SVAR model. For instance, the same model can be identified restricting the oil supply elasticity to be zero, only to imply an oil demand elasticity which is equal to $-1$; or can be identified restricting the oil demand elasticity to be zero, only to imply an oil supply elasticity which is implausibly large.

2.4 The Role of Oil Demand and Oil Supply Elasticities

One could argue that an oil supply elasticity of, say, 0.01 is not meaningfully different from an elasticity of, say, 0.05. In this subsection, we show that this is not the case. Small changes in the oil price elasticities have large and material implications for quantifying the determinants of fluctuations in oil prices and oil production.

Figure 3 illustrates this result by plotting—for our baseline model—the share of the forecast error variance at horizon zero for oil prices (left panel) and for oil production (right panel) that is attributable to oil shocks, as a function of the oil supply elasticity $\eta_s$. Figure A.5 in the Appendix plots the same variables for the Kilian (2009) model estimated using the full sample.

Consider the case in which the supply elasticity is assumed to be zero, the value used in Kilian (2009). By assumption, setting a zero supply elasticity implies that oil production is exogenous within the month. Accordingly, as shown by the red line in the right panel of Figure 3, all of its forecast error variance is accounted for by the oil supply shock. However, an additional implication of setting a zero supply elasticity is that, as shown in the left panel, almost all of the forecast error variance of oil prices—about 95 percent—is explained by the oil-specific demand shock. This result holds regardless of the indicators for global demand that are included in the VAR: as shown in
Figure 3: Forecast Error Variance Decomposition – Impact Horizon
Baseline VAR Specification

![Figure 3: Forecast Error Variance Decomposition – Impact Horizon Baseline VAR Specification](image)

**Note:** Fraction of forecast error variance in oil price (left panel) and oil production (right panel) at horizon zero explained by oil supply shocks (solid red line), oil demand shocks (dashed blue line), and the sum of oil supply and oil-specific demand shocks (dashed-dotted black line).

Figure A.5, under the Kilian (2009) model, this share rises to 99 percent. This happens because, when \( \eta_S = 0 \), the demand schedule is very elastic (see Figure 2). Accordingly, shocks to oil supply move oil production along a relatively flat demand curve, and cause little movements in oil prices. Thus, Kilian (2009)'s identification implies a disconnect between the drivers of oil production and the drivers of oil prices: oil production moves in response to shocks to oil supply, whereas oil prices move in response to shocks to oil demand.\(^{10}\)

The disconnect between the drivers of oil production and of oil prices under Kilian (2009)’s identification allows us to revisit the taxonomy proposed by Stock and Watson (2016), who distinguish between two identification approaches in the VAR literature on oil. In the first approach, which they label “oil exogenous,” oil prices are ordered first in a Cholesky factorization, and innovations to oil prices are typically assumed to derive from shocks to oil production. In the second strategy—which builds on the identification assumptions in Kilian (2009)—it is assumed that oil production responds

\(^{10}\)Figure A.6 in the Appendix plots the share of the variance of the 24-month ahead forecast error for oil prices and oil production. The dependence of the relative importance of the oil-specific supply and demand shocks on the oil supply elasticity is similar to that at horizon zero. Yet, at a 24-month horizon, about 40 percent of movements in oil prices and 20 percent of movements in oil production are due to global factors. We provide additional details on the importance of global factors in Section 4.
to oil demand shocks only with a lag, so that the oil supply elasticity is zero. However, the distinction between the two approaches is mostly semantic. The evidence in Figure 3 shows that, in practice, the two approaches are nearly equivalent: in the “oil exogenous” approach it is assumed that one shock explains, on impact, all the forecast error variance of oil prices; the approach in Kilian (2009) finds that an oil-specific demand shock also explains nearly all of the variance of oil prices. Figure A.7 illustrates this point by showing that the impulse responses to an oil price shock under the “oil exogenous” identification and to an oil-specific demand shock under the restriction $\eta_S = 0$ of Kilian (2009) are nearly identical.\footnote{Stock and Watson (2016) argue that, because the “oil exogenous” identification was initially used to study the effects of the oil shocks of the 1970s, oil price shocks were then interpreted as equivalent to oil supply shocks. By contrast, Kilian (2009) shows that such shocks should be interpreted as oil-specific demand shocks.}

Figure 3 shows how assuming a larger oil supply elasticity differs from the exogenous oil price assumption and from Kilian (2009)’s identification strategy. In particular, small but positive values of the oil supply elasticity significantly alter the relative importance of oil-specific supply and demand shocks in accounting for fluctuations in the price of oil. In particular, a value of $\eta_S$ close to 0.1, similar to that selected by our identification strategy, implies that the two shocks are equally important drivers of oil prices and oil production. Thus, for sufficiently upward-sloping supply curves and sufficiently downward-sloping demand curves, the two oil shocks jointly affect oil prices and production.

3 Targets for the Oil Supply and Demand Elasticities

In this section, we provide empirical evidence about the price elasticity of global supply and demand for crude oil by estimating instrumental variable (IV) panel regressions. This evidence provides the basis for the target elasticities that we impose to identify the SVAR model.

3.1 A Stylized Model of the Global Oil Market

We start from a small, stylized empirical model that provides the basis for estimating oil supply and oil demand elasticities starting from individual countries’ oil production data. In the empirical model
we assume that the global oil market consists of \( N \) countries, and has the following structure:

\[
\Delta q_{S,i,t} = \eta_S \Delta p_t + u_{S,i,t}, \forall i = 1, \ldots, n, \tag{11}
\]

\[
\Delta q_{D,i,t} = \eta_D \Delta p_t + u_{D,i,t}, \forall i = 1, \ldots, n, \tag{12}
\]

\[
\sum_{i=1}^{N} \omega_{S,i} \Delta q_{S,i,t} = \sum_{i=1}^{N} \omega_{D,i} \Delta q_{D,i,t}. \tag{13}
\]

Equation (11) is the oil supply schedule in country \( i \). According to this equation, the log change in country \( i \)'s production of crude oil \( \Delta q_{S,i,t} \) for month \( t \) depends on the log change in the price of crude oil \( \Delta p_t \) and on a country-specific oil supply shock \( u_{S,i,t} \). Equation (12) is the oil demand schedule in country \( i \). According to this equation, the log change in country \( i \)'s consumption of crude oil \( \Delta q_{D,i,t} \) for month \( t \) depends on the log change in the price of crude oil and on a country-specific oil demand shock \( u_{D,i,t} \). The coefficients \( \eta_S \) and \( \eta_D \) denote the price elasticity of supply and demand, respectively.

We assume, for simplicity, that there are common demand and common supply elasticities across countries, but we relax these assumptions in the robustness exercises presented below.

Finally, Equation (13) is the global market-clearing condition. According to this condition, changes in global oil production (weighted by the country’s production share \( \omega_S \)) must be equal to changes in global oil consumption (weighted by the country’s consumption share \( \omega_D \)). This formulation of the global oil market allows for individual countries to run oil trade imbalances. Through this formulation we implicitly assume that changes in global oil inventories play a secondary role in shaping the ups and downs of oil supply and oil demand. This working hypothesis is supported by the analysis in Section 5, in which we show that augmenting the baseline VAR to include the change in global oil inventories has only a modest effect on the results.

We can express the change in the equilibrium oil price as follows:

\[
\Delta p_t = \sum_{i=1}^{N} c_{S,i} u_{S,i,t} + \sum_{i=1}^{N} c_{D,i} u_{D,i,t}, \tag{14}
\]

where the reduced-form coefficients \( c_{S,i} \) and \( c_{D,i} \) depend on the elasticities \( \eta_S \) and \( \eta_D \), and on the country weights \( \omega_{S,i} \) and \( \omega_{D,i} \).\(^{12}\) Equation (14) shows that the equilibrium oil price depends on the

\(^{12}\) With two countries only, the equilibrium price can be written as follows (omitting the time subscripts for sim-
supply and demand shocks realized in each country. The straightforward implication is that running country-specific OLS regressions based on either Equation (11) or Equation (12) would yield biased estimates of \( \eta_S \) and \( \eta_D \), since, for each country \( i \), the regressor \( \Delta p_i \) is correlated with the shocks \( u_{S,i,t} \) and \( u_{D,i,t} \). In order to circumvent this problem, we use large exogenous declines in oil production in other countries as instrumental variables for oil prices in Equations (11) and (12). Intuitively, if events leading to oil supply disruptions in other countries are truly exogenous, they should affect oil supply and oil demand in a particular country only through their effect on prices. This way, we obtain unbiased estimates of \( \eta_S \) and \( \eta_D \) by regressing production and consumption in each country against the component of prices that is explained by the exogenous shocks in other countries.\(^{13}\)

Our approach yields unbiased estimates when the oil supply and oil demand shocks identified in a specific country are orthogonal to oil shocks taking place in other countries within the same month. In our application, this condition is violated during the Iraq invasion of Kuwait in August 1990, which led to supply disruptions in multiple countries. For this reason, we classify shocks that take place in multiple countries within the same month as one single episode, and impose the orthogonality assumption at the episode-level aggregation. Additionally, in our stylized model, we rule out any interactions between the oil market and global economic activity, unlike in our SVAR model, in which industrial production affects, and responds to, global oil production. We control for these channels by controlling for industrial production in the estimation of the country-specific regressions.

### 3.2 Construction of the Instruments

We describe the construction of the instruments in three steps. First, we use the example of the Gulf War to revisit the evidence on the oil supply elasticity presented in Kilian and Murphy (2012), in which a single episode of a large decline in oil production in one set of countries is used to infer the global oil supply elasticity. Second, we generalize this example using data—described in

\[
\Delta p = \frac{\omega_{S,1} u_{S,1} + \omega_{S,2} u_{S,2}}{\eta_S - \eta_D} + \frac{\omega_{D,1} u_{D,1} + \omega_{D,2} u_{D,2}}{\eta_S - \eta_D},
\]

so that \( c_{S,1} = \frac{-1}{\eta_S - \eta_D} \omega_{S,1} \), and \( c_{D,1} = \frac{-1}{\eta_S - \eta_D} \omega_{D,1} \), for instance. Accordingly, a sufficient condition for supply shocks to reduce the price and demand shocks to increase the price is that the supply elasticity \( \eta_S \) is positive and the demand elasticity \( \eta_D \) is negative.

\(^{13}\)Mohaddes and Pesaran (2016) use a GVAR model to analyze the international transmission of country-specific oil supply shocks. As in the GVAR approach, we study the global oil market by exploiting the information contained in country-level data on oil production and oil consumption. However, an important upshot of our approach is that we focus on episodes of large changes in a country’s oil production in order to derive estimates of both oil demand and oil supply elasticity.
Appendix A—on oil production for 21 countries for the sample from 1985 to 2015, and compile a list of 28 episodes of large, country-specific declines in oil production. We then use narrative records to classify these episodes as either exogenous (e.g., the result of wars or natural disasters) or endogenous (e.g., the response to falling oil prices). Third, for each individual country we construct an instrument that sums for, each month, all the exogenous declines in oil production occurring in the other countries.

The Gulf War

Prima facie, the events of the Gulf War appear ideal candidates to derive estimates of the oil supply elasticity. On August 2, 1990, Iraqi forces invaded Kuwait. Within one month, oil production in Iraq and Kuwait fell by about 4 and 2.8 percent of global production, respectively. Amidst such decline and the associated fears about a potential escalation of the war, the real price of crude oil rose in August 1990 by 44.3 percent. Kilian and Murphy (2012) argue that in August 1990 there was ample spare capacity in global oil production, as well as unanimous willingness among oil producers to increase production to offset the adverse price effects of market fears about a wider war. In August 1990, all oil producers excluding Iraq and Kuwait increased production only by 1.17 percent. According to their analysis, the implied oil supply elasticity could not exceed \( \eta_S = \frac{1.17}{44.3} \equiv 0.0258 \), a value that they take as an upper bound.

However, case studies like the Gulf War can be deceptive, as the same event can easily lend itself to multiple interpretations. In fact, our interpretation is that geopolitical events that unfolded in August 1990 show how even this single episode can be used to rationalize an oil supply elasticity that is more than twice as large as Kilian and Murphy (2012)’s upper bound.

First, in August 1990 oil production in the United Arab Emirates (U.A.E.) was disrupted by geopolitical events that were clearly linked to the inception of the Gulf War. In other words, there was a shock to \( u_{S,i} \) for the U.A.E. that was also related to the same sequence of events that ultimately led to the shocks \( u_{S,i} \) in Iraq and Kuwait. Notably, on July 17, 1990, then-Iraq’s President Saddam Hussein openly threatened to use force against Arab oil-exporting nations if they did not curb their excess production. Even though President Hussein did not mention countries by name, all commentators agreed that the threats were clearly aimed at the U.A.E and Kuwait (Ibrahim, 1990). During
the same week, Abu Dhabi National Oil Co. announced that it intended to reduce crude production by up to 30 percent for an indefinite period. While this action was officially taken to ensure that the U.A.E. complied with the OPEC production agreement, the timing and the fact that the U.A.E. had been in violation of the agreement for a prolonged period suggest that the move was taken in reaction to the pressure imposed by the unprecedented barrage of strong political intimidation by Iraq’s top officials. All told, the U.A.E. lowered oil production in August by 19.5 percent, about 0.66 percent of global production. The implication for the analysis at hand is that oil production in the U.A.E. should be excluded from global oil production for the calculation of the oil supply elasticity. Consequently, since in August 1990 global oil production excluding Iraq, Kuwait, and the U.A.E. increased by 1.97 percent, the estimate of $\eta_S$ becomes 0.045, nearly twice as large as the estimate in Kilian and Murphy (2012).

A second consideration is that, in the late 1980s and early 1990s, the energy sector in the Soviet Union was in disarray, hit by a sequence of adverse shocks amidst a deep and protracted economic and political crisis. In 1989, the Soviet energy sector did not attain its contracted obligations, and crude oil production fell by 2.9 percent. In 1990, crude oil production fell by 6.4 percent, with a decline of -1.1 percent from July to August. In the same year, the Soviet Union faced unprecedented difficulties in fulfilling energy requirements for their East Bloc allies. The sharp and prolonged decline in production, which continued throughout the dissolution of the Soviet Union, was due to various factors related to labor unrest, substantial cuts in capital investment, and widespread shortage of equipment. The analysis of these developments opens the possibility of excluding oil production in the Soviet Union from the calculation of the oil supply elasticity, as the Soviet Union was hit in the same month by negative oil supply shocks. When the Soviet Union is factored out, global production excluding Iraq, Kuwait, the U.A.E., and the Soviet Union rose 2.76 percent in August 1990. Accordingly, the oil supply elasticity $\eta_S$ becomes 0.062, more than twice as large as Kilian and Murphy (2012)’s upper bound.

---

14 Sources: Oil Daily, July 17 and 18, 1990.
15 Sources: Oil Daily, April 18, July 16, and November 21, 1990.
### Table 1: Large Country-Specific Declines in Crude Oil Production

<table>
<thead>
<tr>
<th>Date</th>
<th>Country</th>
<th>Event</th>
<th>Exogenous?</th>
<th>% of Global Oil Prod.</th>
<th>% of Domestic Oil Prod.</th>
<th>Narrow Criterion</th>
<th>Broad Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1985</td>
<td>Saudi Arabia</td>
<td>OPEC</td>
<td></td>
<td>-1.62</td>
<td>-25.36</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jun 1985</td>
<td>Nigeria</td>
<td>OPEC</td>
<td></td>
<td>-0.67</td>
<td>-22.34</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jan 1986</td>
<td>Nigeria</td>
<td>OPEC</td>
<td></td>
<td>-0.79</td>
<td>-27.28</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Apr 1986</td>
<td>Norway</td>
<td>Strike</td>
<td>✓</td>
<td>-0.97</td>
<td>-62.34</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Apr 1986</td>
<td>Qatar</td>
<td>N/A</td>
<td></td>
<td>-0.28</td>
<td>-48.46</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jul 1986</td>
<td>Egypt</td>
<td>OPEC</td>
<td></td>
<td>-0.26</td>
<td>-20.13</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 1986</td>
<td>Nigeria</td>
<td>OPEC</td>
<td></td>
<td>-0.79</td>
<td>-26.35</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 1986</td>
<td>Saudi Arabia</td>
<td>OPEC</td>
<td></td>
<td>-2.64</td>
<td>-25.09</td>
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<td>✓</td>
</tr>
<tr>
<td>Oct 1986</td>
<td>Egypt</td>
<td>OPEC</td>
<td></td>
<td>-0.90</td>
<td>-26.24</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jan 1987</td>
<td>Saudi Arabia</td>
<td>OPEC</td>
<td></td>
<td>-2.06</td>
<td>-22.46</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mar 1987</td>
<td>Ecuador</td>
<td>Earthquake</td>
<td>✓</td>
<td>-0.40</td>
<td>-82.56</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 1987</td>
<td>Iran</td>
<td>War</td>
<td>✓</td>
<td>-0.97</td>
<td>-22.24</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jan 1988</td>
<td>U.A.E.</td>
<td>OPEC</td>
<td></td>
<td>-0.81</td>
<td>-28.63</td>
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<td>✓</td>
</tr>
<tr>
<td>Jan 1989</td>
<td>Saudi Arabia</td>
<td>OPEC</td>
<td></td>
<td>-2.82</td>
<td>-26.10</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Aug 1990</td>
<td>Iraq</td>
<td>War</td>
<td>✓</td>
<td>-4.03</td>
<td>-70.59</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Aug 1990</td>
<td>Kuwait</td>
<td>War</td>
<td>✓</td>
<td>-2.90</td>
<td>-94.59</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Aug 1990</td>
<td>U.A.E.</td>
<td>Geopolitics</td>
<td>✓</td>
<td>-0.66</td>
<td>-19.51</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>May 1992</td>
<td>Russia</td>
<td>Anticipated</td>
<td></td>
<td>-0.86</td>
<td>-6.32</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jun 1997</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>✓</td>
<td>-1.07</td>
<td>-54.33</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dec 2000</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>✓</td>
<td>-2.07</td>
<td>-51.87</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jun 2001</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>✓</td>
<td>-2.61</td>
<td>-61.96</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Apr 2002</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>✓</td>
<td>-1.95</td>
<td>-51.69</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dec 2002</td>
<td>Venezuela</td>
<td>Geopolitics</td>
<td>✓</td>
<td>-2.83</td>
<td>-65.68</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Apr 2003</td>
<td>Iraq</td>
<td>War</td>
<td>✓</td>
<td>-1.88</td>
<td>-96.14</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 2005</td>
<td>U.S.A.</td>
<td>Hurricane</td>
<td>✓</td>
<td>-1.33</td>
<td>-18.94</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 2008</td>
<td>U.S.A.</td>
<td>Hurricane</td>
<td>✓</td>
<td>-1.38</td>
<td>-20.51</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mar 2011</td>
<td>Libya</td>
<td>Civil War</td>
<td>✓</td>
<td>-1.38</td>
<td>-77.61</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Note:** The entries in the table list large drops in oil production identified by using the criteria described below.

- **Narrow criterion:** Domestic oil production in month $t$ drops by more than 2 percent of global oil production.
- **Broad criterion:** Domestic oil production in month $t$ drops by: (1) more than 0.66 percent of global oil production, and (2) more than 19.5 percent and (3) more than 4 standard deviations; OR domestic oil production in month $t$ drops by: (1) more than 1 percent of global oil production, and (2) more than 50 percent; OR domestic oil production relative to a 6-month moving average drops by more than 5 times its standard deviation.

### Quantitative Criteria and Narrative Analysis

We now construct our instruments, generalizing the analysis of the Gulf War to multiple episodes of large exogenous declines in oil production. We focus on large declines since they are easy to detect, using quantitative criteria, and to classify, using narrative analysis. Appendix D describes our classification in greater detail, characterizing the episodes either as endogenous—cuts in production taken in response to oil price changes—or as exogenous, cuts in production due to geopolitical events or natural disasters.
Table 1 presents the candidate country–month pairs selected according to our criteria. Table 2 lists the subset of candidate episodes that we classify as exogenous and that we use to construct our instruments.

As shown in Table 1, our first criterion—the narrow criterion—selects observations in which oil production in country $i$ during month $t$ drops by more than 2 percent of global oil production, a threshold inspired by the drop in oil production experienced by Iraq and Kuwait in August 1990. As shown in the table, the narrow criterion selects only eight country–month pairs: Saudi Arabia in September 1986, January 1987, and January 1989; Iraq and Kuwait in August 1990; Iraq in December 2000 and June 2001, and Venezuela in 2002.

Our second criterion—the broad criterion—defines multiple thresholds calibrated to select a larger set of declines in a country’s oil production. These declines are either relative to a country’s own past production, or relative to global production. In particular, the first three thresholds in Table 1 are designed to capture the declines in oil production of Iraq, Kuwait, and the U.A.E. in August 1990. All told, as shown in Table 1, the broad criterion singles out 28 country–month pairs.

Having selected candidate country–month pairs, we move to the construction of the instruments. We use narrative analysis to classify each country–month pair decline as either endogenous or exogenous, and to combine any declines in a particular month into an exogenous episode identifying a supply shock. In doing so, our classification identifies August 1990 as the only exogenous episode involving multiple countries. In that month, the change in production in U.A.E., consistent with our narrative analysis, is classified as part of the shock—even for the narrow instrument—and not as part of the endogenous response. By contrast, in April 1986—the only other month that features two episodes—the only exogenous episode is the cut in production in Norway following a major strike of unionized oil workers. We classify the drop in production in Qatar that happened in the same month as endogenous. Qatar is an OPEC member and we could not find any information about a major event that could have led to an exogenous disruption in oil production.

For the narrow criterion, our narrative analysis classifies the declines in Saudi oil production as endogenous, as they were part of an effort by OPEC to support falling oil prices. We classify the remaining declines as exogenous, with the August 1990 decline being the largest. Accordingly, our narrow criterion identifies four unique, exogenous episodes of declines in oil supply. By the same
<table>
<thead>
<tr>
<th>Date</th>
<th>Country</th>
<th>Event</th>
<th>% of global Oil Prod.</th>
<th>Narrow Instrument[a]</th>
<th>Broad Instrument[b]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 1986</td>
<td>Norway</td>
<td>Strike</td>
<td>-0.97</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mar 1987</td>
<td>Ecuador</td>
<td>Earthquake</td>
<td>-0.40</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 1987</td>
<td>Iran</td>
<td>Iraq-Iran War</td>
<td>-0.97</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Aug 1990</td>
<td>Iraq+Kuwait+U.A.E.</td>
<td>Persian Gulf War</td>
<td>-7.65</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Oct 1995</td>
<td>Mexico</td>
<td>Hurricanes</td>
<td>-1.37</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jun 1997</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>-1.07</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dec 2000</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>-2.07</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Jun 2001</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>-2.61</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Apr 2002</td>
<td>Iraq</td>
<td>Geopolitics</td>
<td>-1.95</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dec 2002</td>
<td>Venezuela</td>
<td>Political Unrest</td>
<td>-2.83</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Apr 2003</td>
<td>Iraq</td>
<td>Second Persian War</td>
<td>-1.88</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 2005</td>
<td>U.S.A.</td>
<td>Hurricane</td>
<td>-1.33</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sep 2008</td>
<td>U.S.A.</td>
<td>Hurricane</td>
<td>-1.38</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mar 2011</td>
<td>Libya</td>
<td>Civil War</td>
<td>-1.38</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Note:** The entries in the table list the episodes of large drops in oil production that comprise the narrow and broad instruments. See text for additional details.

\[a\] Narrow instrument: Drops in oil production that satisfy the narrow criterion discussed in Table 1 and are classified as oil supply shocks in the narrative analysis presented in Appendix D.

\[b\] Broad instrument: Drops in oil production that satisfy the broad criterion discussed in Table 1 and are classified as oil supply shocks in the narrative analysis presented in Appendix D.

token, for the broad criterion, our narrative analysis identifies 14 unique exogenous episodes.16

The exogenous episodes are used to construct the two instrumental variables described in Table 2. The narrow instrument measures the decline in global oil production in months and countries identified on the basis of the narrow criterion and classified as exogenous. Consistent with our narrative analysis of the previous subsection, the drop in oil production in the U.A.E. in August 1990 is included in the construction of the instrument, since the decline in oil production in U.A.E. was caused by the same set of events that led to the Persian Gulf War. Similarly, the broad instrument consists of the decline in global oil production in months and countries identified on the basis of the broad criterion and classified as exogenous.

16Between 1985 and 1989, we classify three out of 14 episodes as exogenous. The three exogenous episodes are a strike in Norway, an earthquake in Ecuador, and the impact of escalation in the Iran-Iraq war on Iran’s oil installations. Ten episodes are classified as endogenous, including eight cuts in oil production decided by OPEC. The remaining episode (Qatar in April 1986) is excluded as we could not find sufficient information to classify it. From 1990 onwards, we classify 11 out of 12 episodes as exogenous. The only endogenous episode is May 1992 in Russia.
Table 3: Panel Estimates of the Price Elasticity of Crude Oil Supply and Demand

<table>
<thead>
<tr>
<th></th>
<th>1. OLS</th>
<th>2. Narrow IV</th>
<th>3. Broad IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(A.) Price elasticity of crude oil supply</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \eta_S )</td>
<td>0.021</td>
<td>0.054</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td>[0.014]</td>
<td>[0.015]</td>
<td>[0.037]</td>
</tr>
<tr>
<td>First-stage F stat.</td>
<td>-</td>
<td>18.08</td>
<td>15.58</td>
</tr>
<tr>
<td>Total Obs.</td>
<td>7719</td>
<td>77</td>
<td>274</td>
</tr>
<tr>
<td>Countries</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Unique Episodes</td>
<td>372</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td><strong>(B.) Price elasticity of crude oil demand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \eta_D )</td>
<td>-0.014</td>
<td>0.002</td>
<td>-0.074</td>
</tr>
<tr>
<td></td>
<td>[0.013]</td>
<td>[0.066]</td>
<td>[0.047]</td>
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<tr>
<td>First-stage F stat.</td>
<td>-</td>
<td>18.07</td>
<td>15.58</td>
</tr>
<tr>
<td>Total Obs.</td>
<td>2819</td>
<td>32</td>
<td>104</td>
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<tr>
<td>Countries</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Unique Episodes</td>
<td>372</td>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>

Note: The dependent variables in each specification are \( \Delta q_{S,i,t} \) (panel A) and \( \Delta q_{D,i,t} \) (panel B), the monthly change in the production and consumption, respectively, of crude oil in country \( i \). The entries in the rows of the table corresponding to \( \eta_S \) and \( \eta_D \) denote the estimates of the coefficients associated with the monthly change in the real price of crude oil. The second column reports OLS estimates, while columns 3 and 4 show the IV estimates using the narrow and broad instruments described in Table 2 and in the text. Standard errors are reported in brackets. All specifications include country fixed effects. All specifications in panel B include the current and lagged log change in industrial production in country \( i \) and during month \( t \), as well as current and lagged log changes in aggregate industrial production in advanced economies and in emerging economies. All OLS regressions in column 1 include month of the year dummy variables.

### 3.3 IV Estimates of the Oil Elasticities

We use monthly data from 1985 to 2015 on production and consumption of crude oil available from the U.S. Department of Energy. Data on crude oil production are available for 21 countries, while data on petroleum consumption are available for eight OECD countries.\(^{17}\) Appendix A provides additional details. We estimate the following instrumental variable specifications:

\[
\Delta p_{i,t} = \pi_i + \gamma \Delta v_{t} + \epsilon_{i,t}, \tag{15}
\]

\[
\Delta q^S_{i,t} = \alpha_{S,i} + \eta^S \Delta p_{i,t} + u^S_{i,t}, \tag{16}
\]

\[
\Delta q^D_{i,t} = \alpha_{D,i} + \eta^D \Delta p_{i,t} + \Psi X_{i,t} + u^D_{i,t}, \tag{17}
\]

\(^{17}\)The petroleum consumption data are not seasonally adjusted. Although there are seasonal patterns in oil consumption in some (but not all) countries, our results are similar using seasonally adjusted data.
where $\pi_i$, $\alpha_{S,i}$, and $\alpha_{D,i}$ are country fixed effects, $\tau$ is the time-subscript identifying the episodes of exogenous declines in oil production. Equation (15) is the first-stage regression, where $\Delta v_\tau$ is the instrument, given by the percent change in global oil production directly accounted for by the episodes listed in Table 2. Equations (16) and (17) are the IV regressions for supply and demand. In line with the SVAR model presented in Section 2, Equation (17) controls for contemporaneous and lagged country-specific, advanced economies, and emerging economies log changes in IP, all denoted by the vector $X_{i,\tau}$. For each country $i$, we construct country-specific instruments by excluding exogenous episodes involving that country. For instance, the instrument for the U.S. excludes the months of September 2005 and September 2008, the two months during which hurricanes Katrina and Gustav disrupted crude oil and petroleum products production in the U.S.

Panels (A) and (B) in Table 3 report results from the estimation of equations (16) and (17). The OLS column presents the estimates when, trivially, $\hat{\Delta p} = \Delta p$, while the last two columns show the IV estimates using the narrow and broad instruments discussed in the previous section.\footnote{The IV regressions do not include the months in which no exogenous oil shocks occur. For instance, the regressions that include the narrow instrument include only 77 observations, that is, four observations each for 21 countries, less the six observations in Table 2 in which a country-month pair was subject to an exogenous decline in oil production, less one missing observation for Russia whose data start in January 1992. We verified that including the months without exogenous oil shocks in our regressions has little bearing for our estimates.}

Starting with Panel (A), column 1 reports the OLS estimate of the global oil supply elasticity $\eta_S$, which is 0.021. Column 2 presents the IV estimates using the narrow instrument. The oil supply estimate constructed using IV is 0.054, larger than its OLS counterpart and statistically different from zero. The last column presents the IV estimates using the broad instrument. The estimated oil supply elasticity is even larger, 0.077, and remains statistically significant. As shown in the table, our instrumental variables are strong instruments for oil prices, with F-statistics above 15. Importantly, if we treat the August 1990 drop in production in the U.A.E. as endogenous, using the narrow instrument, the estimate of $\eta_S$ drops to 0.028 (with a standard error of 0.020). This number is very close to the 0.026 estimate of Kilian and Murphy (2012) discussed earlier. By contrast, using the broad instrument, the estimate of $\eta_S$ rises to 0.051, a value twice as large as the estimate of Kilian and Murphy (2012). Thus, if we rely on a small number of episodes, our estimate of $\eta_S$ is influenced by the events of August 1990, just like the estimate of Kilian and Murphy (2012).\footnote{The estimate of $\eta_S$ by Kilian and Murphy (2012) has a natural interpretation as an IV regression based on two observations: one baseline observation in which changes in oil prices and changes in oil production are assumed to be}
The use of a larger set of episodes induces a larger estimate of the oil supply elasticity irrespective of the classification of the drop in oil production in the U.A.E.

The results for the oil supply elasticity are robust to the use of additional, alternative estimation methods for panel data. For instance, using the broad instrument specification, the estimate of the oil supply elasticity becomes 0.078 using random effects, and 0.109 using the mean group estimator of Pesaran and Smith (1995). In addition, to rationalize our aggregate estimate of the supply elasticity, it is instructive to look at country–specific estimates, which uncover some heterogeneity across countries, confirming the wisdom that not all oil producers respond uniformly to movements in oil prices. For instance, when we estimate the broad instrument specification allowing for different oil supply elasticities across (1) Saudi Arabia, (2) OPEC countries excluding Saudi Arabia, and (3) non-OPEC countries, we find values of 0.22, 0.19, and −0.01, respectively. These results are consistent with the fact that OPEC producers, in particular Saudi Arabia, are the group with the largest volume of spare capacity that can be used to offset disruptions in oil supply within a short period of time.

Panel (B) shows the estimates of the oil demand elasticity. The demand elasticity appears to be less precisely estimated than its oil supply counterpart. The OLS estimate of the oil demand elasticity, $\eta_D$, is −0.014 but it is not statistically different from zero. A similarly low elasticity is obtained using the narrow instrument: in this case, the elasticity is zero up to the second decimal place. As for the oil supply elasticity, the use of a larger set of episodes induces a larger estimate, in absolute value, of the oil demand elasticity. Using the broad instrument specification, the demand elasticity becomes −0.074, with a standard deviation of 0.047.

The results for the oil demand elasticity obtained using the broad instrument are robust to the use of alternative estimators. For instance, the estimate of the oil demand elasticity becomes −0.075 using random effects, while it becomes −0.038 using the mean group estimator of Pesaran and Smith (1995). Thus, our estimates of the oil demand elasticity are consistent with the existing empirical evidence. In line with Dahl (1993) and Cooper (2003), we find that the demand elasticity of crude oil is small and around −0.05. Compared to these studies, our contribution is to provide an alternative

---

20The associated standard deviations are 0.15, 0.06, and 0.05, respectively. As OPEC producers account for about 40 percent of global output, the “production-weighted” average of these estimates is again close to the estimated value of 0.077 for the global supply elasticity reported in Table 3.
identification strategy based on IV regressions. We also find that the demand elasticity of crude oil is substantially smaller than the demand elasticity of gasoline, which is typically estimated to be around \(-0.3\). There are at least three reasons for this difference. First, as discussed in Hamilton (2009), crude oil represents about half the retail cost of gasoline, and thus the price elasticity of demand for crude oil should be about half that for retail gasoline. Second, data on petroleum consumption, as discussed in Appendix A, measure, among other things, refinery production and crude oil products supplied. The contracts underlying the deliveries of such products are typically negotiated at least a month in advance, and thus petroleum consumption might be less responsive to changes in prices within a given month relative to gasoline consumption. Third, as was the case with the estimates of the supply elasticity, the events of August 1990 have a large weight in shaping the estimates of the oil demand elasticity. In that month, despite of a large rise in oil prices, oil consumption fell sharply in the European countries included in our dataset, but rose in Korea, Japan, Canada, and the United States.\textsuperscript{21}

4 VAR Results

In this section, we first present the impulse responses implied by our SVAR. We then discuss results from the forecast error variance decomposition and the historical decomposition to characterize the contribution of the identified shocks to fluctuations in oil–market variables and economic activity. In our identification strategy, we set the target supply and demand elasticities to the point estimates reported in Table 3 for the case of broad instrument, that is, \((\eta^*_S, \eta^*_D) = (0.077, -0.074)\). We choose the estimates obtained using the broad instrument as they rely on a large set of observations, and as they hew closely to the VAR admissible set shown in Figure 2. We set the weights matrix \(V\) in Equation (10) to be diagonal, with the entries on the main diagonal equal to the variances associated with the point estimates of the elasticities from Table 3. In our application, the identification selects

\textsuperscript{21}One report form the Congressional Budget Office (CBO, 1991) attributed some of the August 1990 spike in U.S. demand to higher gasoline consumption. According to the same source, a fall in commercial inventories of crude oil (excluding the Strategic Petroleum Reserve), which had been at a near record high at the end of July, also contributed to the rise. The International Energy Agency, in its October 1990 Oil Market Report (IEA, 1990) cited secondary/tertiary stock-building as one of the reasons behind the increase in OECD oil consumption. The IEA conjectured that deliveries in North America increased because some of the secondary/tertiary build that had been expected in July might have occurred in August.
a pair of admissible elasticities for each draw of the reduced-form parameters. The resulting median elasticities are $\eta_S = 0.11$ and $\eta_D = -0.13$.\textsuperscript{22}

4.1 Impulse Responses

The solid lines in the left column of Figure 4 show the median impulse responses of the five endogenous variables to a one standard-deviation oil supply shock, while the shaded bands represent the corresponding 90 percent (light blue) and 68 percent (dark blue) pointwise credible bands. An unanticipated disruption in oil supply reduces production by about 0.8 percent and leads to a persistent increase in oil prices, which rise by 6.5 percent on impact and remain elevated thereafter. On the activity side, the response of IP is markedly different across advanced and emerging economies. IP in advanced economies declines gradually, bottoming out at -0.4 percent two and a half years after the shock. The negative response is consistent with the fact that our sample of advanced economies is, on average, oil dependent. In contrast, IP in emerging economies rises rapidly, peaking after six months at 0.25 percent above its pre-shock level. Hence, emerging economies, which are on average oil independent, experience a boost to economic activity following a supply-driven increase in oil prices.\textsuperscript{23}

The right column of Figure 4 shows the responses to an oil demand shock. The shock leads to an increase in oil prices of about 6 percent and induces a rise in oil production of about 0.7 percent. The near-term response of IP in advanced and emerging economies is similar, with IP increasing mildly in both groups of economies for six months. Thereafter, real activity contracts in advanced economies while remaining elevated in emerging economies, even though the responses are quantitatively small.

Figure 5 traces out the effects of the three global activity shocks. The left and middle columns plot the responses to a shock to activity in the advanced and emerging economies, respectively, while the right column shows the responses to a metal price shock. The three shocks generate correlations that are typical of demand-driven business cycle fluctuations: The increase in real activity in advanced and emerging economies—the latter accompanied by a persistent increase in metal prices—is associated

\textsuperscript{22} Results obtained when using as targets the elasticity estimates obtained under the narrow instrument are similar.

\textsuperscript{23} Iacoviello (2016) finds that oil-exporting countries experience a rise in consumption and GDP following supply-driven increases in oil prices. Peersman and Van Robays (2012) also find that the effects of exogenous oil supply shocks on economic activity are negative for net oil importing countries and insignificant or even positive for net oil exporters.
Figure 4: Impulse Responses to Oil Market Shocks

Note: The solid lines in the left column depict median responses of the specified variable to a one standard-deviation oil supply shock, while those in the right column depict median responses to a one standard-deviation oil demand shock; The light shaded bands represent the 90 percent pointwise credible sets and the dark shaded bands represent the 68-percent pointwise credible sets. All variables are expressed in log changes (multiplied by 100).
Figure 5: Impulse Responses to Global Activity Shocks

Note: The solid lines in the left column depict median responses of the specified variable to a one standard-deviation shock to advanced economies’ activity, those in the middle column depict median responses to a one standard-deviation shock to emerging economies’ activity, and those in the right column depict median responses to a one standard-deviation metal price shock: The light shaded bands represent the 90 percent pointwise credible sets and the dark shaded bands represent the 68 percent pointwise credible sets. All variables are expressed in log changes (multiplied by 100).
Table 4: Forecast Error Variance Decomposition of Selected Variables
24-Month Ahead

<table>
<thead>
<tr>
<th>Shock</th>
<th>Oil Supply</th>
<th>Oil Demand</th>
<th>AE Activity</th>
<th>EE Activity</th>
<th>Metal Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Prices</td>
<td>36.9</td>
<td>20.3</td>
<td>3.2</td>
<td>14.5</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>[26.5; 49.9]</td>
<td>[12.9; 31.2]</td>
<td>[1.4; 7.0]</td>
<td>[6.8; 25.3]</td>
<td>[10.1; 33.2]</td>
</tr>
<tr>
<td>Oil Production</td>
<td>35.3</td>
<td>36.8</td>
<td>9.5</td>
<td>6.1</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>[28.1; 44.3]</td>
<td>[29.1; 45.9]</td>
<td>[4.6; 17.1]</td>
<td>[3.5; 10.6]</td>
<td>[3.9; 15.7]</td>
</tr>
<tr>
<td>AE Activity</td>
<td>8.2</td>
<td>2.2</td>
<td>59.6</td>
<td>11.5</td>
<td>13.6</td>
</tr>
<tr>
<td></td>
<td>[2.8; 18.6]</td>
<td>[0.8; 5.9]</td>
<td>[48.7; 71.1]</td>
<td>[7.5; 17.3]</td>
<td>[6.3; 24.9]</td>
</tr>
<tr>
<td>EE Activity</td>
<td>6.0</td>
<td>5.3</td>
<td>9.0</td>
<td>47.2</td>
<td>26.9</td>
</tr>
<tr>
<td></td>
<td>[1.9; 15.4]</td>
<td>[1.3; 14.1]</td>
<td>[5.6; 14.3]</td>
<td>[35.5; 60.7]</td>
<td>[15.7; 40.5]</td>
</tr>
</tbody>
</table>

Note: The entries in the table denote the posterior median estimate of the portion of the forecast error variance of a specified variable at the 24-month horizon that is attributable to five structural shocks. The 16th and 84th percentiles of the posterior distributions are reported in bracket. See subsection 4.2 for details.

Positive shocks to activity in emerging economies and positive shocks to metal prices induce a persistent increase in oil prices. By contrast, an increase in advanced economies’ activity induces only a mild and short-lived increase in oil prices.

The positive and persistent responses of IP in both advanced and emerging economies to a shock to the metal price index support the view that metal prices are a valid leading indicator of current and expected global activity. Additionally, our findings are also consistent with the literature that emphasizes shocks to commodity prices as drivers of business cycles in emerging economies (IMF, 2015).

4.2 Forecast Error Variance Decomposition

This section explores the relative importance of oil and non-oil shocks in accounting for fluctuations in oil prices and global economic activity. In particular, we are interested in assessing the importance of oil price movements in accounting for shifts in economic activity and the role of oil shocks in driving the global business cycles.

Table 4 shows the variation in the two-year-ahead forecast error variance in oil prices, oil production, advanced economies’ IP and emerging economies’ IP that is attributable to the five structural
shocks identified by our SVAR model. As shown in the first row of Table 4, about 60 percent of the fluctuations in oil prices are due to shocks that originate in the oil market. In particular, shocks to oil supply account for 37 percent of the forecast error variance, while oil-specific demand shocks explain about 20 percent. Movements in global demand are also a significant source of oil price fluctuations, explaining about 40 percent of oil price fluctuations.\textsuperscript{24} Shocks to economic activity in emerging economies and in metal prices are important drivers of oil prices, while the contribution of shocks to economic activity in advanced economies is almost zero. The second row of Table 4 shows that oil production is mostly driven by oil supply and oil demand shocks, which equally account for 35 percent of its volatility.

The third and fourth rows of Table 4 show that, on average, oil-specific shocks contribute little to the volatility in real activity. Oil supply shocks account for 8 and 6 percent of the forecast error variance of advanced economies’ and emerging economies’ IP, respectively. The contribution of oil-specific demand shocks is about 2 and 5 percent for advanced and emerging economies’ activities, respectively. Not surprisingly, activity variables are mostly driven by their own shocks. Yet we find that shocks to metal prices, which are ordered last in our SVAR model, account for about 15 and 25 percent of the forecast error variance of IP in advanced and emerging economies, respectively.

Summing up, our results show that fluctuations in oil prices are primarily driven by oil supply shocks. In addition, movements in oil prices driven by global demand mostly reflect changes in oil demand from emerging rather than advanced economies. We also find that oil shocks have a significant but secondary role in driving IP in both advanced and emerging economies, accounting for slightly less than 10 percent of the variability at business cycle frequency.

\subsection*{4.3 Historical Decomposition}

In this section, we present the historical decomposition of the actual paths of the VAR variables that is attributable to the oil market and global activity shocks.\textsuperscript{25} We give an overview of the 1987–2015 period, presenting the decomposition at an annual frequency computed by taking end-of-year log

\textsuperscript{24} Because the median contribution is calculated for each shock independently, the rows do not sum to 100 percent.

\textsuperscript{25} We compute the historical decomposition using the OLS estimates of the reduced-form parameters. The sample used for the estimation of the reduced-form coefficients includes both actual data and the dummy observations used to implement the Minnesota prior.
changes of the variables. In Appendix B, we zoom in on three important episodes involving large changes in the price of oil: the Asian financial crisis, the global financial crisis, and the fall in the price of oil that started in July 2014 and lasts through the end of our sample period.

Figure 6 shows the decompositions across the whole sample for the price of oil, oil production, and IP in both advanced and emerging economies. Overall, our decomposition shows that most of the fluctuations in the price of oil and in oil production were determined by oil-market specific shocks. Nonetheless, global activity contributed significantly to shaping fluctuations in oil market variables. Shocks to emerging economies and to metal prices played a prominent role, while shocks to advanced economies activity played a modest role. Shocks emanating from the oil market also contributed to fluctuations in advanced economies’ and emerging economies’ real activity. However, the quantitative importance of oil shocks, and, in particular, of oil supply shocks has varied considerably over the past three decades. Oil supply shocks played an important role in the late 1990s and since 2012, but

Note: Sample period: 1986 to 2015. The shaded regions in each panel depict the historical contributions of oil market and global activity shocks to the specified variable, while the solid lines depict the actual series. All variables are expressed in log changes (multiplied by 100).
they had a smaller role in the rest of the sample.

4.4 Summary of Findings

All told, the analysis in this section shows that (1) under our identification, oil supply shocks induce significant movements in oil prices and quantities; (2) shocks to global demand account, on average, for about 25 percent of fluctuations in oil prices, and are important drivers of oil prices during some historical episodes; and (3) shocks that originate in the oil market have heterogeneous effects on activity in advanced and emerging economies.

5 Adding Oil Inventories to the VAR

Our baseline specification abstracts from inventories, by assuming that oil production is fully absorbed by consumption in every period. The total stock of oil inventories are, across countries, a small multiple of the flow of global oil production within a month, thus making it hard to conjecture that changes in inventories can dampen oil price movements caused by large gaps between production and consumption at monthly frequency. For instance, U.S. crude oil stocks are less than twice monthly U.S. crude oil production. However, inventories could in principle quickly move to absorb differences between oil production and oil consumption, in turn affecting the dynamics of the oil market. To account for this possibility, we follow Kilian and Murphy (2014) and Baumeister and Hamilton (2015) and extend our model of the oil market presented in Section 2 to include oil inventories. Define the change in inventories ($\Delta I_t$) as the difference between oil production ($Q_t$) and oil consumption ($C_t$):

$$\Delta I_t = Q_t - C_t.$$  \hspace{1cm} (18)

Recall that our benchmark VAR includes $q_t = 100 \log(Q_t/\bar{Q}_t)$, where $\bar{Q}_t$ is the trend level of production constructed assuming a constant growth rate. Given this scaling, we can express detrended oil consumption as $c_t = q_t - \Delta i_t$, where $\Delta i_t = 100 \Delta I_t/\bar{Q}_t$. This leads to the following structural

\[ 26 \] In 2015, average stocks of crude oil excluding the Strategic Petroleum Reserve were 481 million barrels (Source: US Department of Energy). Average monthly crude oil production was about 285 million barrels (Source: Oil and Gas Journal).
There are three differences compared to our baseline model described in Equations (5)–(9). First, the inclusion of inventories in the VAR changes the dynamics of the model and consequently the estimation of the reduced-form residuals $\varepsilon_t$. Second, inventories enter the oil demand curve described by Equation (20). Third, Equation (24) describes how inventories react to movements in oil-market and macroeconomic variables. The disturbance $u_{i,t}$ denotes inventory-demand shocks that, in concert with oil-specific demand shocks $u_{d,t}$, drive oil demand holding macroeconomic conditions unchanged. The proposed model of inventories follows closely Baumeister and Hamilton (2015), except that we do not allow for measurement error in inventories.

We find that the estimated model with inventories admits a set of demand and supply elasticities that are very similar to the baseline model. Accordingly, the estimated oil supply and demand elasticities are 0.10 and −0.12, respectively, and are nearly identical to those of the baseline model. Table 5 shows the variation in the two-year-ahead forecast error variance in the price of oil, oil production, and oil inventories that is attributable to the three oil shocks identified by the model augmented with inventories. As shown in the first two rows of Table 5, the contribution of inventory-demand shocks to the forecast error variance of oil prices and production is small. In addition, the contribution of oil supply shocks and oil demand shocks (the sum of oil-specific demand and inventory demand shocks) to fluctuations in oil prices and oil production is similar to the baseline model. Finally, as shown in the last row of Table 5, fluctuations in oil inventories are mostly driven by shocks to inventory demand, with a secondary role played by oil-specific demand shocks and a
Table 5: Forecast Error Variance Decomposition of Selected Variables Model with Oil Inventories: 24-Month Ahead

<table>
<thead>
<tr>
<th>Shock</th>
<th>Oil Supply</th>
<th>Oil Demand</th>
<th>Inventory Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Prices</td>
<td>33.9</td>
<td>15.6</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>[23.8; 47.0]</td>
<td>[9.7; 27.5]</td>
<td>[2.8; 9.7]</td>
</tr>
<tr>
<td>Oil Production</td>
<td>37.0</td>
<td>31.5</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>[29.2; 46.1]</td>
<td>[24.8; 39.8]</td>
<td>[3.0; 6.6]</td>
</tr>
<tr>
<td>Oil Inventories</td>
<td>4.8</td>
<td>26.7</td>
<td>60.6</td>
</tr>
<tr>
<td></td>
<td>[3.5; 6.5]</td>
<td>[24.6; 29.1]</td>
<td>[57.8; 63.5]</td>
</tr>
</tbody>
</table>

Note: The entries in the table denote the posterior median estimate of the portion of the forecast error variance of a specified variable at the 24-month horizon that is attributable to three oil shocks. The 16th and 84th percentiles of the posterior distributions are reported in bracket.

negligible role of oil supply shocks.

6 Conclusion

In this paper we identify a SVAR model of the global oil market by using external information from a large panel of countries in order to impose restrictions on the values of the short-run price elasticities of both oil supply and oil demand. In the estimating framework, global demand for oil is jointly captured by industrial production in advanced and emerging economies as well as by an index of metal prices. We find that oil supply shocks account for about 40 percent of oil price fluctuations at business cycle frequencies, while shocks to global demand account for 35 percent. We also show that a drop in oil prices driven by oil supply shocks boosts economic activity in advanced economies, while it depresses economic activity in emerging economies, thus helping explain the muted effects of changes in oil prices on global economic activity.
References


Baumeister, C. and J. D. Hamilton (2015). Structural Interpretation of Vector Autoregressions with Incomplete Identification: Revisiting the Role of Oil Supply and Demand Shocks. Manuscript, University of Notre Dame and UCSD.


Appendices

A  The Data

Industrial Production. We construct a monthly index of industrial production (IP) for advanced economies and emerging economies by aggregating country-level data. We take monthly, seasonally adjusted, total IP excluding the construction industries. For countries where this series is not available, we use monthly, seasonally adjusted, manufacturing industrial production. The initial unbalanced dataset runs from 1960:M1 to 2015:M12 for advanced economies and from 1963:M1 to 2015:M12 for emerging economies. To construct the indexes, we first compute the growth rate of IP for each individual country. For both advanced and emerging economies, we then aggregate the country-specific growth rates by calculating annual weights based on gross domestic production (GDP) in current U.S. dollars from the World Bank’s Global Development Indicators. Next, we obtain the level of industrial production by cumulating the resulting monthly growth series. Both indexes are normalized to take the value of 100 in January 2007. Although the IP data potentially start in the 1960s, we set 1985 as the starting date because 1985:M1 is the earliest observation when our sample includes enough emerging economies so that they account, using today’s GDP weights, for at least 25 percent of emerging economies’ GDP.

Table A.1 lists the countries included in the advanced economies index, while Table A.2 lists the countries included in the emerging economies index. For each country we report the weight in the total index as of 2013 as well as the sample availability. For advanced economies, since 1985—the first observation we use in the estimation—data are available for all countries except Finland, Greece, and Portugal, which are countries with a small weight in the overall index. Data availability is more scattered for emerging economies. From 1985 to the mid–1990s, the emerging economies index is driven mostly by India, Korea, and Mexico. Data for Russia, the third largest country in the panel, become available in 1993, while data for China are available since 1997.

The countries in the sample account, in 2013, for 87 percent of global GDP in current dollars, with 53 percentage points and 34 percentage points of GDP accruing to advanced and emerging economies, respectively. Because of the lack of monthly IP data, the largest economies missing from the sample are Australia, Saudi Arabia, Switzerland, Nigeria, Iran, and the United Arab Emirates, which together account for about 6 percent of global GDP.

The advanced economies in the sample account for 20 percent of global oil production and 41 percent of global oil consumption. The emerging economies in the sample account for 34 percent of global oil production and 39 percent of global oil consumption. (As a consequence, the missing countries account for 13 percent of global GDP, 46 percent of global oil production, and 20 percent of global oil consumption).

Metal Prices. Metal prices are measured from the IMF Metal Price Index, linearly log de-trended and expressed in real terms dividing by the U.S. consumer price index (CPI). The metal price index (code: PMETA) is available at https://www.imf.org/external/np/res/commod/index.aspx.

Oil Market Variables. The real price of oil is the monthly average of the West Texas Intermediate, linearly log de-trended and expressed in real terms dividing by the U.S. CPI index. Data on crude production and consumption are from the International Petroleum section of the Monthly Energy Review published by the U.S. Energy Information Administration (EIA). The data are available at
In that section, Table 11.1a tabulates data on production in OPEC members, Table 11.1b tabulates data on production for non-OPEC countries and world, while Table 11.2 tabulates data for petroleum consumption in eight OECD countries. Petroleum consumption is defined as total petroleum products supplied. For the U.S., as indicated in the Glossary of the EIA’s Monthly Energy Review, petroleum products supplied—including natural gas plant liquids and crude oil burned as fuel—approximately represents consumption of petroleum products because it measures the disappearance of these products from primary sources, i.e., refineries, natural gas-processing plants, blending plants, pipelines, and bulk terminals. For each petroleum product, product supplied in any given period is computed as field production, plus refinery production, plus imports, plus unaccounted-for crude oil minus stock change, minus crude oil losses, minus refinery inputs, and minus exports. In turn, petroleum products include products obtained from the processing of crude oil (including lease condensate), natural gas, and other hydrocarbon compounds.

For the country-panel regressions reported in Section 3, we use oil production data from 1985m1 through 2015m12 for the following 21 countries: Algeria, Angola, Canada, China, Ecuador, Egypt, Indonesia, Iran, Iraq, Kuwait, Libya, Mexico, Nigeria, Norway, Qatar, Russia, Saudi Arabia, United Arab Emirates, United Kingdom, United States, and Venezuela. Data for Russia start in 1992m1. We exclude Gabon, a small producer, due to concerns about data quality. There are eight other missing observations in the regressions involving percent changes in oil production for the following country-month pairs: Ecuador-1987m5, Iraq-1991m3, Iraq-1991m4, Kuwait-1991m3, Kuwait-1991m4, Kuwait-1991m5, Kuwait-1991m6, Libya-2011m9. For these eight observations, the level of oil production in that country in the previous month was zero, thus implying that the percent change in oil production is not defined.

We use oil consumption data for the following eight countries: France, Germany, Italy, United Kingdom, Canada, Japan, South Korea, and the United States.

There are no data on global crude oil inventories. Hence, as standard in the literature, we proxy for global oil inventories by using data on total U.S. oil inventories scaled by the ratio of OECD petroleum stocks over U.S. petroleum stocks.

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### Table A.1: Summary Data on Advanced Economies’ Industrial Production

<table>
<thead>
<tr>
<th>Country</th>
<th>Share of Global GDP</th>
<th>Share of Global Oil Production</th>
<th>Share of Global Oil Consumption</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>22.03%</td>
<td>11.63%</td>
<td>20.78%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Japan</td>
<td>6.46%</td>
<td>0.00%</td>
<td>4.95%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Germany</td>
<td>4.90%</td>
<td>0.00%</td>
<td>2.64%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>France</td>
<td>3.69%</td>
<td>0.00%</td>
<td>1.82%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3.52%</td>
<td>1.00%</td>
<td>1.64%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Italy</td>
<td>2.81%</td>
<td>0.13%</td>
<td>1.41%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Canada</td>
<td>2.42%</td>
<td>4.59%</td>
<td>2.61%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Spain</td>
<td>1.83%</td>
<td>0.00%</td>
<td>1.31%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.12%</td>
<td>0.00%</td>
<td>0.98%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.76%</td>
<td>0.00%</td>
<td>0.34%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.69%</td>
<td>0.00%</td>
<td>0.69%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Norway</td>
<td>0.69%</td>
<td>2.12%</td>
<td>0.27%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Austria</td>
<td>0.56%</td>
<td>0.00%</td>
<td>0.29%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.44%</td>
<td>0.21%</td>
<td>0.17%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Finland</td>
<td>0.35%</td>
<td>0.00%</td>
<td>0.21%</td>
<td>1995–2015</td>
</tr>
<tr>
<td>Greece</td>
<td>0.32%</td>
<td>0.00%</td>
<td>0.32%</td>
<td>1995–2015</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.30%</td>
<td>0.00%</td>
<td>0.15%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.30%</td>
<td>0.00%</td>
<td>0.27%</td>
<td>2010–2015</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0.08%</td>
<td>-</td>
<td>-</td>
<td>1985–2015</td>
</tr>
<tr>
<td><strong>AFE total</strong></td>
<td><strong>53.26%</strong></td>
<td><strong>19.69%</strong></td>
<td><strong>40.85%</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The entries in the table list the countries used in the calculation of the industrial production index in advanced economies. The underlying country indexes refer to total industrial production excluding construction. Data for Japan are on manufacturing industrial production.
## Table A.2: Summary Data on Emerging Economies’ Industrial Production

<table>
<thead>
<tr>
<th>Country</th>
<th>Share of Global GDP</th>
<th>Share of Global Oil Production</th>
<th>Share of Global Oil Consumption</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>12.47%</td>
<td>4.87%</td>
<td>11.69%</td>
<td>1997–2015</td>
</tr>
<tr>
<td>Brazil</td>
<td>3.14%</td>
<td>2.44%</td>
<td>3.34%</td>
<td>2002–2015</td>
</tr>
<tr>
<td>Russia</td>
<td>2.73%</td>
<td>12.45%</td>
<td>3.48%</td>
<td>1993–2015</td>
</tr>
<tr>
<td>India</td>
<td>2.45%</td>
<td>1.05%</td>
<td>4.08%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Korea</td>
<td>1.72%</td>
<td>0.00%</td>
<td>2.69%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Mexico</td>
<td>1.66%</td>
<td>3.32%</td>
<td>2.21%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1.20%</td>
<td>1.02%</td>
<td>1.77%</td>
<td>1993–2015</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.08%</td>
<td>0.00%</td>
<td>0.79%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.82%</td>
<td>0.73%</td>
<td>0.73%</td>
<td>1994–2015</td>
</tr>
<tr>
<td>Poland</td>
<td>0.69%</td>
<td>0.00%</td>
<td>0.57%</td>
<td>1996–2015</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.51%</td>
<td>0.53%</td>
<td>1.38%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Colombia</td>
<td>0.50%</td>
<td>1.16%</td>
<td>0.33%</td>
<td>1990–2015</td>
</tr>
<tr>
<td>Venezuela</td>
<td>0.49%</td>
<td>3.10%</td>
<td>0.90%</td>
<td>1997–2013</td>
</tr>
<tr>
<td>South Africa</td>
<td>0.48%</td>
<td>0.00%</td>
<td>0.64%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.41%</td>
<td>0.75%</td>
<td>0.88%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Singapore</td>
<td>0.40%</td>
<td>0.00%</td>
<td>1.35%</td>
<td>1985–2015</td>
</tr>
<tr>
<td>Israel</td>
<td>0.38%</td>
<td>0.00%</td>
<td>0.25%</td>
<td>1990–2015</td>
</tr>
<tr>
<td>Chile</td>
<td>0.36%</td>
<td>0.00%</td>
<td>0.39%</td>
<td>1991–2015</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.36%</td>
<td>0.00%</td>
<td>0.33%</td>
<td>1998–2015</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>0.30%</td>
<td>1.99%</td>
<td>0.30%</td>
<td>1999–2015</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.27%</td>
<td>0.00%</td>
<td>0.20%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Peru</td>
<td>0.27%</td>
<td>0.12%</td>
<td>0.25%</td>
<td>1990–2015</td>
</tr>
<tr>
<td>Romania</td>
<td>0.25%</td>
<td>0.10%</td>
<td>0.19%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Ukraine</td>
<td>0.24%</td>
<td>0.00%</td>
<td>0.28%</td>
<td>2002–2015</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.18%</td>
<td>0.00%</td>
<td>0.14%</td>
<td>1993–2015</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>0.13%</td>
<td>0.00%</td>
<td>0.08%</td>
<td>1998–2015</td>
</tr>
<tr>
<td>Croatia</td>
<td>0.08%</td>
<td>-</td>
<td>-</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.07%</td>
<td>0.00%</td>
<td>0.08%</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Slovenia</td>
<td>0.06%</td>
<td>-</td>
<td>-</td>
<td>1998–2015</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0.06%</td>
<td>0.00%</td>
<td>0.06%</td>
<td>1995–2015</td>
</tr>
<tr>
<td>Jordan</td>
<td>0.04%</td>
<td>-</td>
<td>-</td>
<td>2002–2015</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.04%</td>
<td>-</td>
<td>-</td>
<td>2000–2015</td>
</tr>
<tr>
<td>Estonia</td>
<td>0.03%</td>
<td>-</td>
<td>-</td>
<td>2000–2015</td>
</tr>
<tr>
<td><strong>EME total</strong></td>
<td><strong>33.86%</strong></td>
<td><strong>33.62%</strong></td>
<td><strong>39.39%</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The entries in the table list the countries used in the calculation of the industrial production index in emerging economies. The underlying country indexes refer to total industrial production excluding construction. Data for Chile, Colombia, Indonesia, Israel, Peru, Philippines, Singapore, South Africa, Thailand, and Venezuela refer to manufacturing industrial production. Data for Mexico are for total industrial production including construction.
Figure A.1: Historical Decomposition: Asian Financial Crisis

Note: Sample period: July 1997 to December 1998. The shaded regions in each panel depict the historical contributions of oil market and global activity shocks to the specified variable, while the solid lines depict the actual series. All variables are expressed in log changes (multiplied by 100) from June 1997.

B Historical Decomposition

The historical decomposition at annual frequency reported in Section 4.3 offers a useful overview about the importance of structural shocks. It nevertheless misses some aspects of the interaction between the oil market and macroeconomic variables that are better revealed by looking at the monthly frequency, which we discuss next for three episodes. The first episode is the Asian financial crisis. The second episode is the period before and after the global financial crisis. The third episode corresponds to the fall in the price of oil that started in July 2014 and lasts through the end of the sample.\(^{28}\)

\(^{28}\)For these three episodes, we calculate the cumulative effects on each variable of shocks that materialized from the onset of the event onwards, setting all previous shocks to zero, which explains why the vertical bars in Figures A.1 to A.3 do not sum to the actual data.
The Asian financial crisis.

Figure A.1 plots the historical decomposition of the model variables for the period of the Asian Financial Crisis from July 1997 to December 1998. The defining feature of this event was a sharp contraction in real activity in emerging economies, as shown in the lower-right panel. The decline in the demand of oil from emerging economies induced downward pressure on oil prices and, together with shocks to metal prices, accounted for about one-third of the decline in oil prices.\footnote{Baumeister and Kilian (2016a) attribute a large portion of the slide to reduced demand for oil, arguably caused by the Asian financial crisis, which was followed by economic crises in other countries including Russia, Brazil, and Argentina.}

Accordingly, our model attributes a major role in the decline of the price of oil to supply shocks. We rationalize this finding by noting that, throughout this period, despite a lower demand for oil from emerging countries, a few oil exporters, most notably Iraq, increased production throughout early 1999. Positive oil-specific demand shocks represented an offsetting factor for oil prices, accounting for about 15 percent of the increase in oil production in late 1997.

The effects on economic activity of disturbances originated in the oil market is positive but...
Figure A.3: Historical Decomposition of Selected Variables: 2014-15 oil slump

Note: Sample period: July 2014 to December 2015. The shaded regions in each panel depict the historical contributions of oil market and global activity shocks to the specified variable, while the solid lines depict the actual series. All variables are expressed in log changes (multiplied by 100) from June 2014.

Economically small in advanced economies, while it is negative and more significant in emerging economies. The drop in oil prices caused by “excess production” in some oil-exporting countries resulted in a decline of 1 percent in emerging economies’ real activity.

B.2 The global financial crisis.

In Figure A.2, we plot the estimated historical decomposition for the period of the global financial crisis from July 2008 to December 2009, which was characterized by a dramatic plunge in oil prices. At the onset of the crisis, the model attributes much of the decline in the price of oil to negative oil-specific demand shocks, because of the simultaneous decline in oil production and the relatively small movements in measures of global activity. The role of global activity shocks as drivers of the price of oil becomes more prominent toward the end of 2008, when the sharp decline in real activity for both advanced and emerging economies becomes evident.

The model also attributes some of the decline in the price of oil to positive supply shocks even
though oil production is consistently below trend. Through the lens of the model, the sharp contraction in global activity at the end of 2008 should have led to an even larger reduction in oil production than observed in the data. The higher-than-expected oil production is rationalized by the model through the oil supply shock, which is the only shock that generates a negative co-movement between oil production and the price of oil. Finally, the decomposition of the real activity variables plotted in the lower row of Figure A.2 shows that shocks originating in the oil market played a limited role in the collapse of economic activity associated with the global financial crisis.

B.3 The 2014–15 slump.

Figure A.3 displays the estimated historical decompositions for the July 2014–December 2015 period, characterized by a major slump in the real price of oil. Throughout the episode, our identification attributes most of the decline in the price of oil to supply shocks. Oil-specific demand shocks contributed to the acceleration in the decline of the price of oil at the end of 2015 and in early 2015. On the one hand, positive shocks to global supply, as detected by the decomposition of global production plotted in the upper-right panel, likely resulted from the enduring expansion in shale oil production. On the other hand, the negative shocks to oil-specific demand were likely due to waning concerns about future availability of oil supplies and thus heightened expectations of future excess supply in global oil markets. These expectations, in turn, presumably reflected a few main factors that include the return to production of oil fields in Iraq and Libya following the end of military threats from extremists, greater market confidence that the expansion in shale oil production would not suddenly lose momentum following the price slump, and OPEC’s unwillingness to cut production. Since early 2015, the decline in the price of oil also began to reflect negative shocks both to emerging economies’ IP and to expectations of global activity as captured by the shock to metal prices.30

As shown in the lower row of Figure A.3, oil shocks had no role in shaping economic activity in advanced economies until mid-2015. Since June 2015, oil supply shocks have added about 1 percent to growth in industrial production in advanced economies. In contrast, oil shocks were part of the headwinds faced by emerging economies since late 2014. The contribution to the decline in industrial output was a little over 0.1 percent as of October 2014, rising subsequently to more than 1 percent at the end of 2015. The boost in economic activity in advanced economies in conjunction with the drag on economic activity in emerging economies of about equal size thus helps explain the muted response of global activity to oil market developments.

30The gap between the vertical bars and the black line in the upper-left panel of Figure A.3 shows that about 30 percent of the decline in oil prices was actually predictable, as it reflected the cumulative effects of earlier shocks, slightly smaller than the 50 percent value found by Baumeister and Kilian (2016b).
Figure A.4: **Oil Demand and Supply Elasticities Implied by the VAR Model: Comparison with Kilian (2009) Model**

![Graph showing oil demand and supply elasticities](image)

**Note:** The black solid line plots the relationship between the price elasticity of oil supply and oil demand implied by the benchmark SVAR model described in Section 2; the red dashed line plots the relationship implied by the Kilian (2009) model, while the green dashed line plots the relationship for the Kilian (2009) model estimated on data from 1985 to 2007. The blue circle corresponds to the elasticities estimated in Section 3 ($\eta_S = 0.077, \eta_D = -0.062$). The green squares correspond to the elasticities selected by our identification scheme applied to the three models. See Section 2 for additional details.
Figure A.5: Forecast Error Variance Decomposition – Impact Horizon Kilian (2009) Model

Note: Fraction of forecast error variance in oil price (left panel) and oil production (right panel) at horizon zero explained by oil supply shocks (solid red line), oil demand shocks (dashed blue line), and the sum of oil supply and oil-specific demand shocks (dashed-dotted black line) implied by the Kilian (2009) model.
Figure A.6: Forecast Error Variance Decomposition – 24-Month Horizon Baseline VAR Specification

Note: Fraction of forecast error variance in oil price (left panel) and oil production (right panel) at the 24-month horizon explained by oil supply shocks (solid red line), oil demand shocks (dashed blue line), and the sum of oil supply and oil-specific demand shocks (dashed-dotted black line) in the benchmark model.
Figure A.7: Impulse Responses to Oil-Specific Demand and Exogenous Oil Price Shocks

Note: The solid lines depict median responses of the specified variable to a one standard-deviation oil shock identified by ordering oil prices first in a Cholesky decomposition; the red-dashed lines depict median responses to a one standard-deviation oil demand shock identified by imposing $\eta_S = 0$; The light shaded bands represent the 90 percent pointwise credible sets and the dark shaded bands represent the 68-percent pointwise credible sets. All variables are expressed in log changes (multiplied by 100).
D Narrative Analysis of Large Drops in Oil Production

This appendix provides a narrative analysis of the episodes characterized by large drops in oil production as listed in Tables 1 and 2. These episodes are identified using the three criteria described in the main body of the paper and reported in the notes of the tables. We use this narrative analysis to classify the episodes and to clarify why we decide either to include or to exclude each one of these in constructing the instruments used in our empirical analysis.

The structure of the sections relative to each episode is as follows. We start by reporting the corresponding change in domestic crude production. Data on crude production is from the International Petroleum section of the Monthly Energy Review published by the U.S. Energy Information Administration (EIA).\footnote{The data are available at \url{https://www.eia.gov/totalenergy/data/monthly/#international}. In that section, Table 11.1a is for OPEC members, while Table 11.1b is for non-OPEC countries.} We express the levels of and the changes in domestic production either in million barrels per day (mbd) or in thousand barrels per day (kbd), as appropriate.

Next, we report the nature of the events as also classified in the third columns of Tables 1 and 2 and we add a brief description of the episode. We then go on to provide a lengthier description of each episode to justify the corresponding classification. As backbones of our narrative description we use two sources. For the episodes from 1991 onward, we rely on information from the Oil Market Report (OMR) of the International Energy Agency (IEA).\footnote{Electronic copies of the Oil Market Report are available only starting in 1990 at \url{https://www.iea.org/oilmarketreport/reports/}.} To complement the information from the Oil Market Report, we also use the Oil Daily published by the Energy Intelligence Group. For the episodes prior to 1991, we rely exclusively on the Oil Daily.\footnote{Microfilms of the various issues of the Oil Daily from 1985 to 1999 were obtained from the Research Library of the Federal Reserve Bank of Dallas.} Finally, at the end of each section we report the list of the publications that we used to characterize the related episode.

May 1985 Saudi Arabia

Change in production:

\[-880 \text{ kbd} \ (-25.36\% \text{ of domestic production, from } 3.470 \text{ mbd in April 1985 to } 2.590 \text{ mbd in May 1985})\]

Nature of the event:

**Endogenous**: Support OPEC prices amid price and quota violations by other cartel members.

Narrative description:

The drop in Saudi Arabia’s output in May 1985 appears to have been driven by its willingness to keep overall OPEC output below the established ceiling amid widespread violations of the agreed quotas and the resulting production increases by several other member countries. For the first five months of 1985, Saudi output averaged only about 3.5 mbd. Saudi Arabia’s quota under the OPEC agreement prevailing at that time was a little less than 4.4 mbd, compared to its peak production four years earlier of about 10 mbd. The Oil Daily reported that the production cut to as little as 2.6 mbd in May may have resulted from Saudi efforts to support the market in the face of unofficial price cutting and breaches of quotas by other OPEC members. The Oil Daily further speculated that these numbers as well as OPEC’s own estimates might have been used as evidence at the OPEC ministerial conference on June 30 in case the Saudis, as expected, had tried to curb widespread price-cutting and overproduction by other members. As also reported by the IEA in its May 1985 Oil Market Report, Saudi Arabia was willing to curb its own production in an effort to keep total OPEC output below
its overall ceiling of 16 mbd. During a meeting of the OPEC ministerial executive council in early June 1985, a message from King Fahd of Saudi Arabia was delivered, saying that his country would no longer bear the burden of absorbing other members’ overproduction.

Sources: Oil Daily, June 5 and June 10, 1985.

**June 1985 Nigeria**

Change in production:

-356 kbd (-24.15% of domestic production, from 1.474 mbd in May 1985 to 1.118 mbd in June 1985)

Nature of the event:

**Endogenous**: Bringing output in line with OPEC price and quota structure to support prices.

Narrative description:

In July, industry sources in the U.S. said that Nigeria’s crude oil production was seen to be near 1.1 mbd, the same level as in June. This level marked a significant cutback in production from the 1.626 mbd output in April and a continuation of the decline which was noted when May production was cut back to 1.474 mbd. The Oil Daily reported that Nigeria was worried about the outcome of the July 22 OPEC meeting and was doing its part. In addition, in the lead-up to past prior to OPEC meetings, Nigerian production had been frequently cut back as a mark of solidarity. During 1985:Q1, estimates of Nigerian oil production ranged as high as 1.7 mbd, but sales began to fall after official prices were raised in February to bring Nigeria into line with a revised OPEC price structure.

Sources: Oil Daily, July 19 and August 12, 1985.

**January 1986 Nigeria**

Change in production:

-449 kbd (-27.29% of domestic production, from 1.646 mbd in December 1985 to 1.197 mbd in January 1986)

Nature of the event:

**Endogenous**: Decline in output decline along with those of other OPEC producers to shore up prices.

Narrative description:

In March 1986, the Oil Daily reported that combined crude output from OPEC countries declined from almost 18 mbd in November and December 1985 to around 17 mbd in January 1986 and to slightly lower levels in February. Over the first two months of 1986, crude output levels in Iran, Iraq, Libya, and Nigeria were below those seen in 1985:Q4 levels.

Sources: Oil Daily, March 10, 1986.

**April 1986 Norway**

Change in production: -537 kbd (-62.37% of domestic production, from 861 kbd in March 1986 to 324 kbd in April 1986)

Nature of the event:

**Exogenous**: Strike of offshore catering workers followed by employers’ lockout of production workers
In early April 1986, negotiations broke off between Norway’s Catering Employees Association (CAF) union representing offshore caterers working on North Sea’s oil fields and employers representatives. Members of the CAF union voted for strike action when employers rejected their demand for a 28 percent wage increase that would have granted them parity with other oil production workers, with the union representing production workers saying that they favored wage harmonization. On April 6, about 670 offshore catering workers went on strike. Employers retaliated immediately by locking out about 3,000 North Sea production workers of all affiliated offshore unions, thus leading to the shut down of Norway’s 900 kbd crude oil production. A few days after the start of the dispute, Norwegian state oil company, Statoil, said it had warned its customers that deliveries might have been suspended, and that a force majeure contract clause on crude shipments might have been declared. On April 25, 1986, offshore caterers called off their strike, after Norway’s government asked Parliament to enact legislation to make arbitration between the two sides compulsory, thus banning the strike. Labor Minister Arne Rettedal, told the press that the dispute could not be allowed to continue, on concerns that it was threatening safety on North Sea fields. With production workers returning to the platforms on the Statfjord field during the weekend of April 26-27, more than two-thirds of Norwegian production were back on stream by April 29.

Sources: Oil Daily, April 3, April 7, April 8, April 9, April 10, April 15, April 18, April 21, April 23, April 24, April 25, and April 28, 1986.

April 1986 Qatar
Change in production:
-157 kbd (-48.46% of domestic production, from 324 kbd in March 1986 to 167 kbd in April 1986)
Nature of the event:
Likely Endogenous: No information available

Narrative description:
We found no material that could help explain the observed production decrease. Since Qatar is an OPEC member, we classified this event as being likely endogenous.

July 1986 Egypt
Change in production:
-150 kbd (-20.13% of domestic production, from 745 kbd in June 1986 to 595 kbd in July 1986)
Nature of the event:
Endogenous: Transitory alignment with OPEC’s intention to reduce output and support prices.

Narrative description:
Even though we could not find information directly explaining the production drop for Egypt in July 1986, several articles from the Oil Daily suggest that it might have been related to its willingness to go along with OPEC’s strategy to curb production and prop up sagging global oil prices. To achieve this goal, Saudi Arabian oil minister Sheik Ahmed Zaki Yamani led for several months an OPEC’s campaign to enlist other non-OPEC producers to cooperate in controlling output and stabilizing prices, warning that prices could collapse further if non-OPEC producers did not cooperate. As early as February 1986, the Oil Daily reported that Egypt, an important non-OPEC producer, had said it was willing to cut its production temporarily by 100 to 150 kbd. During the same month, the
Egyptian oil minister Abdel-Hadi Kandil and his Mexican and Venezuelan counterparts held talks in Cairo about shoring up prices and agreed on several proposals to stabilize the oil market planning to present these to other OPEC and non-OPEC producers. In March, the Vice Chairman of Egyptian General Petroleum Corporation, Hammad Ayoub, said that Egypt was willing to attend any meeting of oil producing countries that might help stabilize the oil market. Subsequently, Egypt was one of the non-member countries that participated in a joint meeting in Geneva of OPEC and non-OPEC producers that followed OPEC's own ministerial conference with the aim of negotiating on output levels that could support prices. At that meeting, Egypt was one of the non-OPEC producers who expressed the willingness to cooperate in reducing production and to help stabilize prices. Despite OPEC's failure to reach an agreement, in early April Egyptian oil minister Kandil said that “the possibility of cooperation is still there if all are sincere” and that OPEC had to show other producers its good intentions and double its efforts to fix prices at $20 a barrel. Ahead of the ministerial OPEC conference to be held at the end of June 1986 in the island of Brioni in Yugoslavia, it was reported that Egypt was one of the non-OPEC producers which expressed the willingness to consider cooperation with OPEC to cut production. At that meeting, ten of OPEC’s 13 members, including Saudi Arabia, reached an agreement to restrain production, with the agreement—described by Iraqi oil minister Qassem Ahmed Taqi as “gentlemen’s agreement”—covering a four-week period until the ministers’ next meeting at the end of July 1986 in Geneva. Some members pointed out to discussions held with non-OPEC producers such as Mexico, Egypt, and Norway as signs that cooperation with these competitors was becoming a real possibility. In light of this information, it is presumable that Egypt reduced its output to follow through with the strategy implied by the “gentlemen’s agreement.” However, while some OPEC and non-OPEC producers began to hold the line on production in July, Saudi Arabia’s crude production continued to swell, rising from about 5.1 mbd in June to 5.7 mbd in July, well above its OPEC quota at that time of 4.353 mbd. Thus, the failure of Saudi Arabia to fall in line with the “gentlemen’s agreement” might help explain why Egypt raised back its production in August 1986.

Sources: February 3, February 6, February 10, February 11, February 26, February 28, March 4, March 11, March 12, March 14, March 18, March 21, April 2, May 20, May 28, June 20, June 25, July 1, July 2, July 17, July 31, August 7, August 12, 1986.

**September 1986 Saudi Arabia**

**Change in production:**

-1.558 mbd (-25.09% of domestic production, from 6.209 mbd in August 1986 to 4.651 mbd in September 1986)

**Nature of the event:**

**Endogenous**: Bringing output in line with OPEC quota to boost prices.

**Narrative description:**

In early August 1986, at the end of its ministerial meeting in Geneva, OPEC announced to have reached a surprise agreement, originally proposed by Iran, according to which 11 of its 13 member countries—including Iraq and Ecuador—would have returned to their former output quotas established in October 1984 in a bid to achieve the targeted production cutback and force up sagging prices. In December 1985, in an attempt to recapture its “fair share” of the global oil market from outside producers, OPEC had abandoned production and price controls. As a result, from late 1985 until the summer of 1986, oil prices had plummeted from an average of $28 to about $10 a barrel. The new plan, which was supposed to come into effect at the beginning of September 1986 and last for at
least two months, was aimed at curbing OPEC’s production by nearly 4 mbd, from approximately 20 mbd back to an estimated 16.7 mbd. A report by the semi-official U.A.E. newspaper Al-Ittihad on August 4 claimed that Saudi Arabian oil minister Sheikh Ahmed Zaki Yamani had already obtained his government’s approval to support the return to production levels similar to those accepted in October 1984. Subsequently, the Oil Daily reported that in mid-September Yamani told Norwegian oil minister Arne Oeien that oil output in the first week of September 1986 was 3.7 mbd, and also that, according to Gulf oil industry sources, Saudi Arabia’s production may have been lower than its OPEC quota of 4.353 mbd during the second week of September. Finally, the Oil Daily stated that OPEC’s crude oil output averaged about 16.5 mbd in mid-September 1986, thus under the 16.8 mbd production ceiling agreed to by the group, and 4 mbd lower than the average 20.5 mbd produced in August, with the steepest cutbacks coming from Saudi Arabia and Iran.

Sources: Oil Daily, August 5, August 12, September 23, September 25, 1986.

**September 1986 Nigeria**

**Change in production:**
-464 kbd (-26.35% of domestic production, from 1.761 mbd in August 1986 to 1.297 mbd in September 1986)

**Nature of the event:**
- **Endogenous**: Bringing output in line with OPEC quota to boost prices.

**Narrative description:**
The decline in crude output during September 1986 reflected Nigeria’s attempt to keep production within the limit of its quota. During August 1986, the Oil Daily reported that Nigeria would make a 25 percent cut in oil production beginning September 1, as revealed by Nigerian National Petroleum Company. Cuts of this magnitude were deemed necessary to bring Nigeria into line with its OPEC quota of 1.3 mbd, as the country had been producing about 1.7 mbd. The cut in production by Nigeria was among the news from OPEC that its members were taking the individual steps required to reduce its output down by about 4 mbd beginning September 1, when a temporary accord reached in early August in Geneva would have come into force. The information received came after Nigeria’s oil minister and OPEC conference President was reported by Nigerian state television as saying that Nigeria would reduce its production from September 1.

Sources: Oil Daily, August 14, 1986.

**October 1986 Egypt**

**Change in production:**
-115 kbd (-12.7% of domestic production, from 905 kbd in September 1986 to 790 kbd in October 1986)

**Nature of the event:**
- **Endogenous**: Cooperation with OPEC’s agreement to bring output in line with quota system to boost prices.

**Narrative description:**
Similarly to the July 1986 episode involving Egypt, we could not find information directly addressing the production drop occurred in October 1986. A couple of articles published in the Oil Daily during the summer of 1986 indicate that the drop might have been related to Egypt’s willingness...
to cooperate with OPEC and curb production in an effort to boost prices. As early as the end of July 1986, the Oil Daily reported OPEC President Rilwanu Lukman saying—amid the negotiations at OPEC’s Geneva meeting initially aimed at achieving voluntary production cutbacks—that all but one non-OPEC producers had agreed to cooperate with the cartel’s efforts to shore up sagging prices. Subsequently, in early August 1986 OPEC oil ministers, after agreeing to curb production, turned their attention to similar cutbacks by non-OPEC producers. The Oil Daily cited reports indicating that five non-OPEC nations had pledged output cuts totaling 500 to 700 kbd as part of OPEC’s efforts to achieve market stability, with Egypt identified among these non-OPEC producers.

Sources: Oil Daily, July 31, August 6, 1986.

**January 1987 Saudi Arabia**

Change in production:

-1.160 mbd (-22.46% of domestic production, from 5.164 mbd in December 1986 to 4.004 mbd in January 1987)

Nature of the event:

**Endogenous**: Shift in strategic emphasis by Saudi Arabia from targeting market share to targeting higher prices.

Narrative description:

The January 1987 output drop reflected a shift in Saudi Arabia’s strategy from keeping production at elevated levels and targeting market share to restraining production and achieving higher prices. The shift began with the ousting at the end of October 1986 of Saudi Arabia’s oil minister Sheikh Zaki Ahmed Yamani, who had been advocating the market share strategy, and culminated with the OPEC’s pact to cut output and return to fixed prices, which was reached at the December 1986 meeting in Geneva and which had the key backing of Saudi Arabia. Saudi Arabia shifted its policy stance after less than a year of increased production that pushed prices down to as low as $9 a barrel in July 1986. After the ousting of Yamani, acting Saudi Arabian oil minister Hisham Nazer led an emergency meeting of key OPEC ministers in Quito in mid-November 1986 to discuss boosting crude prices. The December agreement, reached after 10 days of disputing, called for an across-the-board cut of more than 7 percent in OPEC production for the first half of 1987, thus implying an output reduction of more than 1 mbd, from the temporary output ceiling of 17.0 mbd expiring at the end of 1986 to 15.8 mbd. The agreement also contemplated the return to a fixed price structure fully effective February 1, based on a target average of $18 a barrel. In mid-January 1987, the Oil Daily reported that Saudi Arabia had been pumping an average of about 3.6 mbd during the first half of the same month, significantly below its quota allocated under the OPEC’s agreement.


**March 1987 Ecuador**

Change in production:

-218 kbd (-82.58% of domestic production, from 264 kbd in February 1987 to 46 kbd in March 1987)

Nature of the event:

**Exogenous**: Earthquakes disrupted oil production and transportation equipment.

Narrative description:
On March 5, 1987, two devastating earthquakes in northeastern Ecuador crippled its oil industry, causing damage to pumping and crude transport installations and leading to a halt in crude output. The earthquakes resulted in severe damage to the Trans-Ecuadorian pipeline, the country’s main crude transportation facility, carrying crude oil from the jungle oilfields in the northeast to the Balao marine terminal near Esmeraldas on the Pacific coast. Most of the disruption occurred where the pipeline route follows the banks of the Coca river, in the proximity of the Reventador Volcano, near the epicenter of the quake, which Ecuadorian seismologists said registered six on the 12-point international Mercalli scale. Along this section, about 24 miles of pipeline were destroyed and had to be reconstructed. One pumping station on the pipeline at El Salado, near the confluence of the Salado and Coca rivers, was badly damaged by a landslide triggered by the earthquakes. An 180-meter section of the pipeline attached to a highway bridge over the Aguarico river—also close to the volcano—collapsed. Ecuador’s three refineries continued functioning, but had no access to crude supplies because of the ruptured pipeline. The state oil firm Corporacion Estatal Petrolera Ecuatoriana (CEPE) notified foreign customers that it was declaring force majeure on its crude exports due to the tremor. The earthquakes led to suspension of crude exports for five months, the period required for the completion of repairs to the pipeline and pumping stations.


**September 1987 Iran**

Change in production:

-569 kbd (-22.24% of domestic production, from 2.558 mbd in August 1987 to 1.989 mbd in September 1987)

Nature of the event:

**Exogenous:** Iraq air strikes damaged oil installations.

Narrative description:

The fall in Iranian output during September 1987 to just a little less than 2 mbd and below its quota of 2.369 mbd reflected the disruptions caused by Iraqi attacks on Iran’s oil tankers and installations. At the end of August 1987, Iraqi warplanes hit four Iran oil tankers in the Persian Gulf, attacked Iran’s Raksh offshore oil field, and raided oil and industrial plants in Iranian territory. The attack ended a break of more than six weeks in Iraqi air strikes on Iranian oil installations.

Sources: Oil Daily, September 1, September 17, October 6, and November 4, 1987.

**January 1988 U.A.E.**

Change in production:

-471 kbd (-28.63% of domestic production, from 1.645 mbd in December 1987 to 1.174 mbd in January 1988)

Nature of the event:

**Endogenous:** Compliance with OPEC’s resolve to curb overproduction that glutted the market and weakened oil prices.

Narrative description:

The drop in U.A.E. output at the beginning of 1988 reflected its compliance with OPEC’s resolve to curb the quota violations and the resulting excess production that glutted the oil market since the summer of 1987, leading to a steep fall in prices. Between July and November 1987, OPEC as
a whole produced, on average, more than 19 mbd, while the established output ceiling set in June for the second half of 1987 was 16.6 mbd. The U.A.E. was among the member countries that were violating their quotas. Over the same period, it produced, on average, about 1.85 mbd, nearly twice as much as its assigned national quota of 948 kbd. In mid-December 1987, after several days of negotiations in Vienna, OPEC ministers decided to extend into the first half of 1988 the same terms of the price and quota system prevailing for the second half of 1987. The agreement was signed by 12 of the 13 member countries, with the exclusion of Iraq which was given no quota. It stipulated that the production levels of all member countries would have been 15.06 mbd during the first half of 1988, distributed into national production levels in the same manner as laid out in the previous agreement, with the exception of Iraq, whose earlier quota was 1.54 mbd. Since the conclusion of the OPEC meeting, the U.A.E. announced output cuts effective January 1, 1988. In early January 1988, the Oil Daily cited oil industry sources reporting that Abu Dhabi, the largest producer in the U.A.E., had decided to cut output and had hence ordered operating companies to reduce production by about 400 kbd.


**January 1989 Saudi Arabia**

Change in production:

-1.737 kbd (-26.10% of domestic production, from 6.655 mbd in December 1988 to 4.918 mbd in January 1989)

Nature of the event:

**Endogenous:** Bringing output in line with renewed OPEC quota structure to boost prices.

Narrative description:

The reduction in Saudi Arabia’s output during January 1989 reflected its attempt to bring production in line with a new OPEC agreement signed in late November 1988 in Vienna and aimed at boosting prices. At that meeting, OPEC’s 13 members agreed to set overall production at 18.5 mbd, effective January 1 and valid for the first half of 1989, with the new output ceiling 4 mbd lower than the total 22.5 mbd produced on average during October and November 1988. Under the new agreement, Saudi Arabia’s output quota was temporarily set at 4.524 mbd, 2 mbd below the Kingdom’s production in November 1988, but a bit higher than the previously assigned quota of 4.353 mbd. During the second half of December 1988, the Oil Daily cited a report that Saudi Arabia had cut its commitment to a major Japanese buyer for January 1989 by 40 percent. This development was interpreted as indicating that the OPEC member country was seriously attempting to cut back production based on the new agreement.

Sources: Oil Daily, November 29, November 30, December 5, December 6, December 7, December 22, 1988, January 11, January 18, 1989.

**August 1990 U.A.E.**

Change in production:

-399.5 kbd (-19.51% of domestic production, from 2.047 mbd in July 1990 to 1.648 mbd in August 1990)

Nature of the event:

**Exogenous:** Strong political pressure on U.A.E. to cut production.
The decrease in U.A.E. production registered during August 1990 appeared to be driven by the return of the oil-producing country within the OPEC quota system. At a November 1989 meeting, OPEC agreed on an output ceiling of 22.1 mbd. The U.A.E. was effectively excluded from the agreement after it refused to recognize its allocated quota of about 1.1 mbd. Since then, U.A.E. output had averaged about 2 mbd, a major factor in the ongoing OPEC overproduction which had led to a sharp drop in global oil prices. The decision by the U.A.E. to limit their crude oil output starting in August 1990 followed on the heels of an unprecedented high-profile barrage of strong political intimidation conducted by Iraqi President Saddam Hussein and his top officials as well as diplomatic campaigns with relatively softer tones pursued by other OPEC members such as Iran and Saudi Arabia.

These initiatives were aimed at coercing the U.A.E., along with Kuwait—the other member country targeted as quota-buster—to get in line with OPEC quota compliance and thus adopt production policies that would secure considerably higher oil prices. Around mid-June 1990, Iran’s oil minister, Gholamreza Aqazadeh, criticized both the U.A.E. and Kuwait for exceeding their OPEC quotas, while a statement by Saudi Arabia’s King Fahd called again for other OPEC members to adhere to the May 2 agreement cutting back OPEC production. During the second half of the same month, Iraqi oil minister Issaam al-Chalabi delivered a blistering attack on U.A.E. overproduction, blaming the Gulf country for being the only member still violating the May 2 emergency OPEC accord. A few days later, he blasted the U.A.E. and Kuwait for quota-busting and reserved special scorn for the U.A.E. saying that the Emirates had rejected OPEC offers for quota parity with Kuwait at 1.5 mbd by asking for even more than Kuwait’s quota.

According to the Oil Daily, Chalabi’s two strong statements were taken to reflect President Saddam Hussein’s increasing exasperation with Iraqi revenue downturns caused by OPEC overproduction. In particular, his use of the term “intentional harm” brought to mind the report that, at the Baghdad summit the previous month, Saddam Hussein was said to have mentioned that at least one Arab Gulf state was waging economic warfare against the interests of Iraq. At around the same time, Iraqi Deputy Prime Minister Saadoun Hammadi, responsible for economic affairs, paid a visit to U.A.E.’s President Sheikh Zaid al-Nuhayan, delivering a message from President Saddam Hussein that explained the problems that Iraq faced with overproduction driving oil prices down. After the meeting, Hammadi said that Sheikh Zaid had shown “understanding of Iraq’s position.”

On the initiative of the government of Saudi Arabia, the oil ministers of the U.A.E., Qatar, Kuwait, Iraq, and Saudi Arabia met in Jeddah on July 10 and 11 for discussions about the situation in the oil markets and the deterioration in oil prices that had been harming the interests of member countries. The ministers agreed that priority should have been given to restoring health to oil prices and that it was to be achieved through strict, practical, and immediate commitment by all OPEC members to the production ceiling set out in the November 1989 accord, which was to be maintained until prices had risen to an acceptable level. At that high-level meeting, the U.A.E. looked set to rejoin the OPEC quota fold, and the U.A.E. President Sheikh Zayed bin Sultan al-Nahyan pledged to cut their overproduction to 1.5 mbd as part of efforts by OPEC to stabilize global oil prices. On July 13, the Oil Daily noted how reports that Sheikh Zayed had signaled his acceptance of 1.5 mbd as a quota for the Emirates—implying a major cutback for Abu Dhabi—showed the importance that the Middle East’s highest political authorities had attached to getting oil prices up. The pledged figure was about 400 to 500 kbd below what the U.A.E. had consistently claimed and produced. The agreement, which was to be formalized only when OPEC ministers would meet in Geneva on July 25, would freeze the official quotas of all other OPEC members. A couple of days after the Jeddah meeting, U.A.E. oil minister Mana Said Otaiba met in Abu Dhabi with his Iranian counterpart.
Briefing reporters on the results of the visit, he confirmed that the U.A.E. had accepted an oil quota of 1.5 mbd. Otaiba also said that the U.A.E., which was at that time estimated to be producing as much as 2 mbd, had cut its output to the new quota level immediately.

A few days after the Jeddah meeting, Abu Dhabi National Oil Company (ADNOC) informally told buyers of its crude that it intended to reduce production by about 400 kbd for an indefinite period beginning August 1, 1990. Abu Dhabi had been producing at levels of around 1.5 mbd, the bulk of U.A.E.’s crude output. On July 17, President Saddam Hussein launched a verbal attack against some Persian Gulf states charging that they had conspired with the U.S. to depress global oil prices through overproduction. In a speech apparently referring to Kuwait and the U.A.E., Hussein accused certain Gulf Arab states of stabbing Iraq “in the back with a poisoned dagger” by helping send crude oil prices tumbling. He threatened that “if words fail to protect Iraqis, something effective must be done to return things to their natural course and return usurped rights to their owners.” Subsequently, Iraq’s Foreign Minister Tareq Aziz charged that “the attempt by the governments of Kuwait and the U.A.E. to flood the oil market with extra crude is a premeditated and deliberate plan to weaken Iraq and undermine its economy and security.” Finally, following through with the pledge made earlier that month at the Jeddah meeting to cut the overproduction, it was agreed at the OPEC meeting in late July 1990, that the output quota for the U.A.E. would be 1.5 mbd.

Sources: Oil Daily, June 19, June 20, June 26, June 28, June 29, July 3, July 9, July 11, July 12, July 13, July 16, July 17, July 18, July 19, July 20, July 23, July 25, and July 30, 1990.

**August 1990 Iraq**

Change in production:
-2.438 kbd (-70.59% of domestic production, from 3.454 mbd in July 1990 to 1.016 mbd in August 1990)

Nature of the event:
**Exogenous**: Production drop caused by the embargo on Iraqi and Kuwait oil in reaction to the First Persian Gulf War.

Narrative description:

The drop in Iraqi production was the result of the embargo imposed on Iraq after it invaded Kuwait in early August 1990 with an estimated 100,000 battle-hardened troops to oust the ruling emir and set up what most observers said was a puppet government. Immediately after the invasion, U.S. President Bush issued an executive order banning virtually all trade with Iraq, including Iraqi oil imports and exports. In just a few days, Iraq’s vital oil exports were cut by nearly 50 percent as a result of U.S.-led efforts to boycott Iraqi crude oil. Nearly 90 percent of Iraq’s oil exports went through pipelines through Turkey and Saudi Arabia. Iraqi authorities told Turkey’s BOTAS pipeline company that one of the two pipelines which carried Iraqi crude oil through Turkey would be closed “for reasons of marketing.” In addition to cutting flow through the one pipeline, Iraq reduced the flow through the other line by 56 percent. In a key development of the global crisis that began when Iraq sent his armed forces into Kuwait, the U.N. Security Council passed a resolution calling for a complete economic embargo on all goods, including oil, military and civilian equipment, of all Iraqi imports and exports. Iraqi exports stopped when Baghdad was denied the use of its major outlets. The pipelines through Turkey and Saudi Arabia, as well as the tanker route through the Gulf had all been closed. Turkey banned the loading of Iraqi oil at its Mediterranean oil tankers docks, ending Iraqi exports through the BOTAS pipeline which carried Iraqi oil from its Kirkuk and Mosul fields to the Turkish port of Ceyhan. The decision came after a Turkish government cabinet meeting which decided immediately to implement the U.N. Security Council resolution.
Sources: Oil Daily, August 3, August 7, August 8, August 9, September 5, 1990.

**August 1990 Kuwait**

Change in production:

-1.757 kbd (-94.59% of domestic production, from 1.858 mbd in July 1990 to 100 kbd in August 1990)

Nature of the event:

**Exogenous**: Production drop caused by the embargo on Iraqi and Kuwaiti oil in reaction to the First Persian Gulf War.

Narrative description:

As with the event described just above involving Iraq, the drop in Kuwait production was also the result of the total economic and military embargo imposed on Iraq and Kuwait after the troops of Baghdad invaded Kuwait in early August 1990. One week after the invasion, Iraq responded to the rapidly growing opposition to its military moves by announcing that it had annexed Kuwait at the request of the provisional government installed after the takeover of its smaller Persian Gulf neighbor.

Sources: IEA Oil Market Report, October 1, 1990 and Oil Daily, August 8, 1990.

**May 1992 Russia**

Change in production:

-519 kbd (-6.32% of domestic production, from 8.212 mbd in April 1992 to 7.693 mbd in May 1992)

Nature of the event:

**Endogenous (Anticipated)**: Continued decline in crude oil output.

Narrative description:

The June 1992 OMR of the IEA reported that in April of the same year Russian production continued the 12-13 percent annual pace of decline already recorded in 1992:Q1. The year-on-year rate of decline in Russia reflected the severe decline in some of the largest mature fields in western Siberia, continuing to exceed that in the non-Russian republics of the former Soviet Union as a whole. In the July 1992 OMR, the IEA noted that discrepancies and inconsistencies abound among available estimates of oil production in both Russia and the former USSR for the months of April and May. The report also noted that no official or unofficial sources of data on production, measured as deliveries into the main pipeline system showed a smooth month-on-month decline during the first part of 1992. The IEA conjectured that producer associations might have been used any logistical flexibility available to them to take advantage of price movements on the domestic market as well as the effect of the export license review in January and February. Based on partial monthly data, the annual decline in oil output production in Russia in the first four months was almost 13 percent.

Sources: IEA Oil Market Reports, June 5 and July 7, 1992.

**October 1995 Mexico**

Change in production:

-862 kbd (-30.37% of domestic production, from 2.839 mbd in September 1995 to 1.977 mbd in October 1995)
Nature of the event:

**Exogenous:** Damages on oil infrastructure caused by Hurricane Roxanne.

Narrative description:

During mid-October 1995, Hurricane Roxanne left a trail of devastation over Mexico, affecting in particular the southwestern portion of the Gulf of Mexico. State oil monopoly Petroleos Mexicanos (Pemex) reported that Roxanne cut substantially its oil production, with most of the production cuts in the Campeche Bay, beneath which lies the Cantarell giant oil field complex. The hurricane forced Pemex to shut in about 85 percent of production from Campeche bay, which accounted for nearly 70 percent of Mexico’s 2.7 million barrels per day of crude output. Pemex also declared force majeure on its 1.25 million barrels per day of exports due to the protracted closure of ports at Dos Bocas, Cayorcas and Pajripnos. In late October, Pemex said that crude output in its key Campeche Bay production area was back to 75 percent of its normal level but that it would also fail to deliver almost 15 million barrel of crude scheduled for the whole month of October due to force majeure following damage from Hurricane Roxanne. In early November, Tradewind Petroleum Services assessed that in October Hurricane Roxanne led to the shut in of nearly 30 million barrels of crude oil, and that, before returning to normal, Pemex would have lost 35 million to 40 million barrels of production, a notably higher figure than earlier estimates.

Sources: Oil Daily, October 13, 16, 18, 19, and 26, and November 6, 8, and 13, 1995. IEA Oil Market Report, November 8 and December 7, 1995.

**June 1997 Iraq**

Change in production:

-700 kbd (-54.33% of domestic production, from 1.290 mbd in May 1997 to 589 kbd in June 1987)

Nature of the event:

**Exogenous:** Unanticipated completion of the first phase of the “oil-for-food” program.

Narrative description:

In June 1997 Iraq exports declined by about 800 kbd, due to the early and unanticipated completion of the first phase of the Iraqi “oil-for-food” program in late May. Earlier strength in prices resulted in revenues for the second 90-day period of the program slightly exceeding the $1 billion revenue target, so that two cargoes scheduled to be loaded at the Persian Gulf Mina-al-Bakr terminal had to be canceled. With no changes in terminal storage or pipeline fill, the end of the loadings were reflected in lower production starting at the end of May.

Sources: IEA Oil Market Reports, June 6, July 8, and August 8 1997.

**December 2000 Iraq**

Change in production:

-1.460 mbd (-51.87% of domestic production, from 2.815 mbd in November 2000 to 1.355 mbd in December 2000)

Nature of the event:

**Exogenous:** Suspension of exports under the “oil-for-food” program.

Narrative description:

On November 30, 2000, Iraq suspended its oil exports under phase 8 of the “oil-for-food” program, as the UN and the Baghdad government were not able to reach an agreement about the December
price formulas for Iraqi export sales. Under the program, Iraq exports transited through the Mediterranean port of Ceyhan in Turkey and the Persian Gulf port of Mina al-Bakr in Iraq. As of the second half of November, overall exports were running at 2.3 mbd. The 180-day phase 9 of the program was authorized to begin on December 6 1991, but it remained suspended. Eventually, oil-for-food exports were interrupted for 12 days, but even though they resumed on December 13, overall Iraqi supply for the month fell by 1.6 mbd, as resumed exports remained low and sporadic. In fact, with little storage capacity at Mina al-Bakr, and the tanks at Ceyhan full since mid-December, oil fields in Iraq were partly or fully shut down.


**June 2001 Iraq**

Change in production:

-1.769 mbd (-61.96% of domestic production, from 2.854 mbd in May 2001 to 1.086 mbd in June 2001)

Nature of the event:

**Exogenous:** Disagreement with the U.N. Security Council over the terms of the “oil-for-food” program.

Narrative description:

Following the U.N. Security Council’s decision to extend the Iraqi “oil-for-food” program for one month instead of the normal six months, on June 4 Iraq halted exports under the program, taking 2.1 mbd of supply out of the market, further indicating that the suspension would have lasted for one month. The UN Security Council resolution on June 1 to extend the program by 30 days instead of 180 days was intended to give Council members time to review and negotiate a revised “smart” sanction plan proposed by the UK and the US, which would lift restrictions on civilian goods but tighten the control on military-related supplies and smuggling.

Sources: IEA Oil Market Reports, June 12 and July 13, 2001.

**April 2002 Iraq**

Change in production:

-1.300 mbd (-51.69% of domestic production, from 2.515 mbd in March 2002 to 1.215 mbd in April 2002)

Nature of the event:

**Exogenous:** Disagreement with the U.N. Security Council over the terms of the “oil-for-food” program.

Narrative description:

On 8 April, Iraq announced a 30-day suspension of its oil-for-food exports. Iraqi output, as a combination of the UN exports, border trade and domestic consumption, fell by 1.2 mbd, thus leading to the loss of 40 to 50 million barrels of crude. This move was sanctioned by Iraqi president Saddam Hussein, in support of Palestinians and designed to pressure supporters of Israel to push for an amicable peace solution. Saddam Hussein called for Islamic countries to unite to broaden the oil embargo. Iran and Libya announced tentative support for such a measure, but only if all Islamic Gulf states fully participated in it. About 1.8 mbd of Iraqi exports were lost from the market through early May. Iraq resumed exports under the UN program on May 8.
Sources: IEA Oil Market Reports, April 10 and May 13, 2002.

**December 2002 Venezuela**

Change in production:

-1.952 mbd (-65.68% of domestic production, from 2.972 mbd in November 2002 to 1.020 mbd in December 2002)

Nature of the event:

**Exogenous**: General national strike led to substantial fall in crude oil production.

Narrative description:

A general national strike began in Venezuela on December 2, resulting from protracted political conflict between President Chavez and his opponents. Opponents of the Chavez government were calling for a mid-term referendum on his leadership. Stoppages by workers, including port staff, pilots, shipping operatives and employees of state oil company PDVSA did cut oil output substantially, causing force majeure to be declared on crude and products exports and crude runs at refineries within Venezuela to be reduced to minimum operating levels. Because of the strike, crude production in Venezuela during December 2002 fell by nearly 2 mbd. In addition, other liquids, including upgraded heavy crude production, fell by more than 500 kbd, bringing the overall Venezuelan production loss to about 74 million barrels.


**April 2003 Iraq**

Change in production:

-1.316 mbd (-96.14% of domestic production, from 1.369 mbd in March 2003 to 52.873 kbd in April 2003)

Nature of the event:

**Exogenous**: Supply disruptions following military actions of the Second Persian Gulf War.

Narrative description:

In April 2003, due to supply disruptions following military actions, Iraq production fell by 1.3 mbd. Limited pipeline exports of crude from northern fields to Syria and Turkey continued until around mid-April. In contrast, southern operations were thought to have ceased soon after the war began in March. US forces were reported to have closed the Iraq-Syria pipeline around April 15. With Ceyhan port storage full to capacity at the same time, and with coalition forces having captured northern facilities, crude production (and refining operations) there came to a complete halt soon after mid-month. After extinguishing a limited number of oil well fires, and having first sealed and checked production facilities for sabotage, southern area production was started up once more on April 23, while northern area production resumed around April 27. However, volumes remained limited.

Sources: IEA Oil Market Reports, April 10 and May 13, 2003.

**September 2005 U.S.A.**

Change in production:

-985 kbd (-18.94% of domestic production, from 5.198 mbd in August 2005 to 4.214 mbd in September 2005)

Nature of the event:
**Exogenous**: Adverse impact of Hurricanes Katrina and Rita.

Narrative description:

In September 2005, Hurricanes Katrina and Rita led to the loss of nearly 1.0 mbd, equivalent to nearly 80 percent of U.S. crude production from the Gulf of Mexico and to almost 20 percent of total U.S. crude production. Severe damage affected elements of upstream infrastructure, with production recovery being further hampered by inoperable pipelines, processing plants, terminals and refineries. From late August 2005, the cumulative loss of crude supply was about 50 million barrels. Louisiana authorities also reported 165 kbd of oil production shut-in within the state’s onshore and shallow offshore boundaries. Damage to pipelines and onshore processing facilities as well as workplace displacement represented the real impediment to supply recovery. The US Minerals Management Service (MMS) reported at the end of September that Katrina did more damage to sub-sea pipelines than originally thought. Pipeline and processing constraints kept crude oil production shut-in for longer than would otherwise been the case. The October IEA OMR estimated that in addition to the crude oil losses, a further loss of 180 kbd of NGL may have been incurred.

Sources: IEA Oil Market Report, October 11, 2005.

**September 2008 U.S.A.**

Change in production:

-1.026 mbd (-20.51% of domestic production, from 5.006 mbd in August 2008 to 3.979 mbd in September 2008)

Nature of the event:

**Exogenous**: Adverse production impact of Hurricanes Gustav and Ike.

Narrative description:

In September 2008, heavy hurricane outages in the Gulf of Mexico had a major negative impact on U.S. production. As of early October 2008, over 40 percent of U.S. crude production in the Gulf of Mexico remained off line amid shuttered pipeline links in the aftermath of Hurricanes Gustav and Ike. More specifically, 582 kbd of Outer Continental Shelf (OCS) crude production remained shut-in after the passing of Hurricanes Gustav and Ike, representing 45 percent and 39 percent, respectively, of pre-storm production levels. In addition, the IEA estimated that 150 to 200 kbd of regional shallow water and onshore crude and NGL production might also have been off line. As was the case after Hurricanes Katrina and Rita in 2005, the continued unavailability of offshore pipelines remained a key impediment to restoring production, more so than damaged production facilities per se. All told, the IEA assumed that oil outages averaged 1.4 mbd in September 2008, with cumulative total oil losses amounting to 45 million barrels by end-September.

Sources: IEA Oil Market Report, October 8, 2008.

**March 2011 Libya**

Change in production:

-1.040 mbd (-77.61% of domestic production, from 1.340 mbd in February 2011 to 300 kbd in March 2011)

Nature of the event:

**Exogenous**: Attacks on oil producing fields and infrastructure in retaliation of exports by opposition to Colonel Gaddafi.
In March 2011, Libyan output fell by nearly 80 percent, plummeting by an average 1.34 mbd to only 300 kbd, following three separate attacks by Colonel Gaddafi’s government forces on oil producing fields and infrastructure in the rebel-controlled eastern region of the country. The attacks targeted oil infrastructure at the country’s largest field, Sarir, in the Sirte Basin, as well as oil fields in the Waha and Messla areas. The three fields were producing around 100 kbd, down sharply from the 420 kbd seen before hostilities erupted in late-February. The attacks were likely in retaliation for the opposition’s first export of crude to international markets. In fact, the attacks came on the heels of the first crude cargo exported by the opposition from Tobruk, but exports were suspended until security could be improved.

Sources: IEA Oil Market Report, April 12, 2011.