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Oil shocks and global economy

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ABSTRACT

This paper analyzes how global economic activity reacts to shocks in the crude oil market, allowing that such reactions may change over time by using a Time-Varying Parameter Vector Autoregression model. Our findings show that an unanticipated disruption in oil supply leads to a relevant decline in global economic activity at any period of time considered (1973:08–2019:06) and at any response horizon, with impacts being relatively similar over time. An unexpected expansion in aggregate demand meaningfully boots global economic activity at any period of time and at any response horizon. In contrast, an unexpected oil-specific demand increase only has a short-lived substantial effect on global economic activity for the shocks produced in the early 2000s, the global financial crisis and the shocks occurred in the last years of the 2010s. These findings are in line with those of Baumeister and Hamilton (2019) who, using a time-invariant model, found that oil supply shocks reduce global economic activity, but oil consumption-demand shocks do not.

1. Introduction

The BP Statistical Review of World Energy 2020[2] shows that oil was still in 2019 the main primary energy consumption in the U.S. (39.1% of global primary energy consumption), total Europe (36.3%), total OECD countries (38.4%) and the world (33.1%). Thus, crude oil market seems to be the largest commodity market and any change in this market may have consequences on other commodity markets (see, e.g., Sari et al., 2010) and on the economy (see Hamilton, 1983, 2011; Kilian and Baumeister, 2016; among many others).

The related literature on the relationship between oil price and economic growth has established a negative link between increases in oil price and economic downturns for net oil importing countries. Thus, Hamilton (1983) stated that 7 out of the 8 postwar U.S. recessions (with the 1960–61 recession being the exception) were preceded by an oil price increase. More recently, Hamilton (2011) has not only confirmed this statement, but he has also extended it by claiming that the last three U.S. recessions[3] before the COVID-19 (July 1990–March 1991, March 2001–November 2001, and December 2007–June 2009) have been also preceded by a rise in oil price.[4] Other authors such as Jiménez-Rodríguez and Sánchez (2005), Cologni and Manera (2009), and Blanchard and Galí (2010) also found a negative impact of oil price increases on economic activity for net oil importing economies different from the U.S. The effects of oil price shocks on economic growth in net oil exporting countries have been included in some analyses of advanced economies (see, for example, Burbidge and Harrison, 1984; Jiménez-Rodríguez and Sánchez, 2005; Peersman and van Robays, 2012), showing that there were positive effects on economic activity in some oil-exporting economies and negative in some others. There has also been a large body of research looking at the effect of oil price shocks on emerging, developing and low-income net oil-exporting economies (see, e.g., Mehrara, 2008, who considered 13 oil-exporting countries; Farzanegan and Markwardt, 2009, who analyzed Iran; Berument et al., 2010, who analyzed 16 MENA countries, with most of them being net oil exporters). These studies have shown evidence in favor of a positive effect of oil price increases on economic growth for mostly net oil exporters. Therefore, the empirical literature has shown evidence of a negative impact of oil price shocks on the economy for

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2 See https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf.

3 See the NBER's business cycle dating at https://www.nber.org/cycles.html.

4 See Oladosu et al. (2018) for a meta-analysis of U.S. oil price elasticity of GDP and Herrera and Rangaraju (2020) for a review of the short-run price elasticity of oil supply and demand.

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Table 1
Prior distributions.

Parameters		
	Prior family	Coefficients
β_0	$N(\hat{\beta}_{OLS}, k_\beta \times V(\hat{\beta}_{OLS}))$	$k_\beta = 4$
A_0	$N(\hat{A}_{OLS}, k_A \times V(\hat{A}_{OLS}))$	$k_A = 4$
$log\ \sigma_0$	$N(\log \hat{\sigma}_{OLS}, k_\sigma \times I_n)$	$k_\sigma = 1$
Hyperparameters		
	Prior family	Coefficients
Q	$IW(k_Q^2 \times pQ \times V(\hat{\beta}_{OLS}), pQ)$	$k_Q = 0.01$ $pQ = 60$
$S_{j,}\ j = 1, 2$	$IW(k_S^2 \times pS_j \times V(\hat{A}_{j,OLS}), pS_j)$	$k_S = 0.1$ $pS_j = j + 1$
W	$IW(k_W^2 \times pW \times I_n, pW)$	$k_W = 0.01$ $pW = n + 1$

Note: N and IW denote the normal and independent inverse-Wishart distributions. $\hat{\beta}_{OLS}$, $\hat{A}_{OLS}$ and $\hat{\sigma}_{OLS}$ are OLS estimates in a time-invariant VAR model for the training sample (which includes 60 observations). $V(\hat{\beta}_{OLS})$ and $V(\hat{A}_{OLS})$ are the corresponding estimator of the covariance matrix of $\hat{\beta}_{OLS}$ and $\hat{A}_{OLS}$, respectively.

net oil importing countries, but a positive one for mostly net oil exporting economies.

There have been few studies that (directly/indirectly) analyze the impact of oil price shocks on a measure of global economic activity, with Baumeister and Hamilton (2019) being the most influential analysis. These authors consider a Structural Vector Autoregression (SVAR) model[5] and find that an oil price increase due to a reduction in oil production reduces global economic activity, but an oil price increase due to an increase in oil consumption demand does not have a significant impact on it.[6]

Another strand of the literature considers a Global-Vector Autoregression (G-VAR) model to study the consequences of oil shocks on each country included in the global model by considering the interlinkages that exist among these countries (see, for example, Dees et al., 2007; Cashin et al., 2014; Mohaddes and Pesaran, 2016, 2017).[7] Despite the fact that this model does not consider the effects on any measure of global economic activity, it provides an idea about the impact of oil shocks on global economy given that the percentage of world GDP that represents the countries included is greater than 80%.

The previous literature on the effects of oil shocks on global economy has not considered the possibility that the responses to oil shocks may change over time given that they use time-invariant parameter models (G-VAR or SVAR models). To the best of our knowledge, no empirical research exists addressing the question of how global economic activity may respond differently to oil shocks over time. There have been some authors that have studied the varying effects of oil shocks on the U.S. economic growth (Baumeister and Peersman, 2013a), the stock market return (Kang et al., 2015; Castro et al., 2021), the euro area real exports (Riggi and Venditti, 2015), the U.S. industrial production (Kapetanios et al., 2019) or the U.S. effective exchange rate (Castro and Jiménez-Rodríguez, 2020) by using a Time-Varying Parameter (TVP) VAR model,[8] but none of them has analyzed how the reaction of global economy to an oil shock may vary over time.[9] However, this analysis of the response of global economy to oil shocks of different nature is relevant since it determines what the most appropriate reaction by investors and domestic policy makers should be in order to minimize the adverse effects or amplify the positive effects (if any) for each shock and each period.

The aim of our study, therefore, is to analyze how global economic activity reacts to shocks in the crude oil market allowing that such responses may change over time. To do so, we consider a TVP-VAR model that includes a measure of global economic activity, the world crude oil production and the real price of oil. This model is estimated by using a Bayesian approach following Primiceri (2005) and Del Negro and Primiceri (2015).

The rest of the paper is organized as follows. Section 2 describes the data. Section 3 presents the methodology. Section 4 reports the main empirical results. Section 5 draws some concluding remarks.

2. Data

In order to analyze the response of global economy to shocks in the crude oil market, we first have to choose the most appropriate measure of global economic activity.

There is no consensus in the literature about the best measure of global economic activity. On the one hand, there are some low frequency measures of global economic activity used in the literature such as annually real world GDP provided by the World Bank (https://data.worldbank.org/) and quarterly real GDP of OECD countries provided by OECD (https://data.oecd.org/). On the other hand, there are several high frequency measures. First, the monthly index of OECD industrial production has been widely used in the literature (see, for instance, Côté, 1986; Ciccarelli and Mojon, 2010) as a proxy of global economic activity. This measure assumes that industrial sector is a good representation of the economy and OECD countries are representative of the world economy. As Ravazzolo and Vespignani (2020) indicated, these assumptions were well accepted before 1990 because manufacturing sector was the most important part of the economic activity and economic growth basically occurred in advanced economies. However, divergences between industrial production index and GDP growth were brought to light in the 2001 recession (see, e.g., Steindel, 2004). Second, a variation of this measure, the monthly industrial production index of OECD economies + 6 non-OECD emerging economies (Brazil, China, India, Indonesia, Russia and South Africa)[10] has been also used (see, e.g., Fueki et al., 2021).[11] Third, Kilian (2009) developed a

[5] Kilian (2009) considers a SVAR model of global crude oil market (which includes a monthly measure of global economic activity) and shows that an increase in oil price may have different impacts on U.S. macroeconomic variables on the basis of the underlying cause of such increases. Kilian and Murphy (2012) focus on the impact of oil shocks on the real price of oil by using the same SVAR model for the global crude oil market as Kilian (2009), but with an identification based on a combination of sign restrictions and plausible elasticity bounds.

[6] Kilian and Murphy (2014) and Baumeister and Hamilton (2019) include oil inventories when they model the global market for crude oil. While the former authors mainly analyze the impact of oil shocks on the real price of oil, the latter focus on the effects on global economic activity.

[7] Mohaddes and Pesaran (2016, 2017) also add a specific oil price equation to the G-VAR model.

[8] Authors such as Herrera and Pesavento (2009), Blanchard and Galí (2010) and Blanchard and Riggi (2013) consider the possibility of different responses of the specific country analyzed to oil price shocks by splitting the sample into two subsamples. Blanchard and Galí (2010) also use a bivariate rolling VAR approach to obtain the rolling impulse response functions to oil price shocks.

[9] As Primiceri (2005) highlighted, while time varying coefficients may reflect the existence of nonlinearities or/and a time variation in the lag structure of the model, time varying variance–covariance matrix may capture possible heteroscedasticity of the shocks and nonlinearities in the contemporaneous links among the variables included in the model.

[10] The OECD countries and 6 non-OECD emerging economies represented more than 80% of world GDP in 2020. Most of OECD economies and four out of six non-OECD emerging economies are net oil-importing countries, with Canada, Mexico and Norway being currently the only net oil exporting countries among the OECD economies and Brazil and Russia being the ones among the 6 non-OECD emerging economies. The UK is currently a net oil importer, but it has been also a net oil exporter during many years.

[11] This index was available from OECD up to October 2011, but it was discontinued as of that date. However, Baumeister and Hamilton (2019) have extended this index beyond that date (https://sites.google.com/site/cjsbaumeister/research). See Appendix C of Baumeister and Hamilton (2019) for an explanation of how this index was extended.

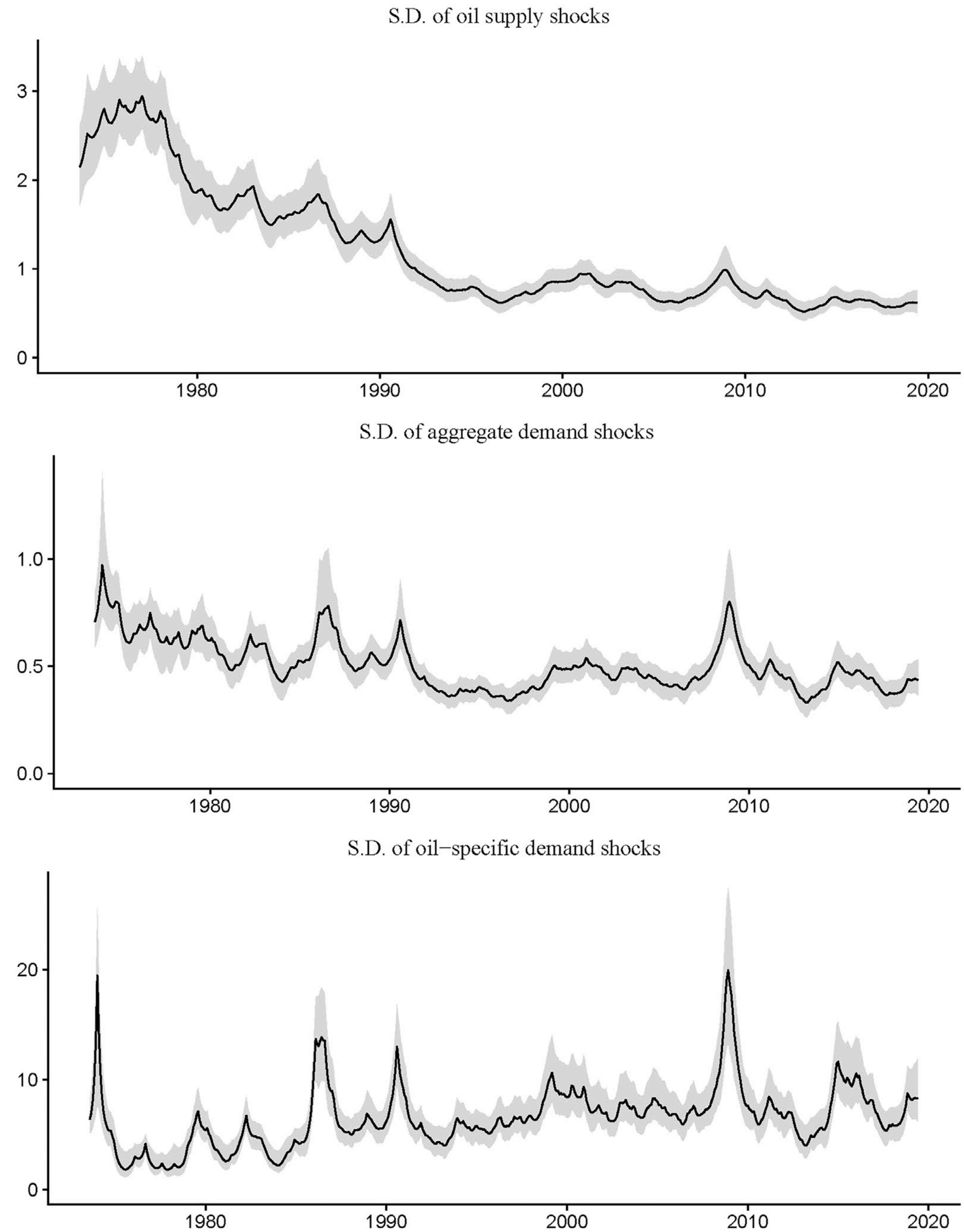

Fig. 1. Time-varying standard deviations. Note: This Figure presents the time-varying standard deviations of each structural shock for the period 1973:08–2019:06 derived from the estimation of the TVP-VAR model. The black solid line represents the posterior median estimates and the gray area displays 68% posterior credible sets. It is worth mentioning that the scale is different for each panel because it would not be easy to distinguish the differences in the standard deviations of the first two structural shocks if we used the same scale for all of them since the scale of the last panel is much larger than that of the others.

measure of monthly global economic activity based on ocean dry bulk cargo freight rates and reported updated rates of growth in his web page.[12,13] This measure has been also broadly considered in the literature (see, e.g., Apergis and Miller, 2009; Baumeister and Peersman, 2013b). However, Hamilton (2021) has shown that the Kilian's (2009) measure presents problems related to the normalization. Kilian (2019) has argued that the problem presented by Hamilton (2021) has to do with a coding mistake and the index can be used as originally intended

[12] See https://sites.google.com/site/lkilian2019/research/data-sets.

[13] Kilian and Zhou (2018) stated that the level of the Kilian's (2009) index does not have an intrinsic meaning and pointed out four benefits and three disadvantages with respect to other proxies such as global real GDP and global industrial production.

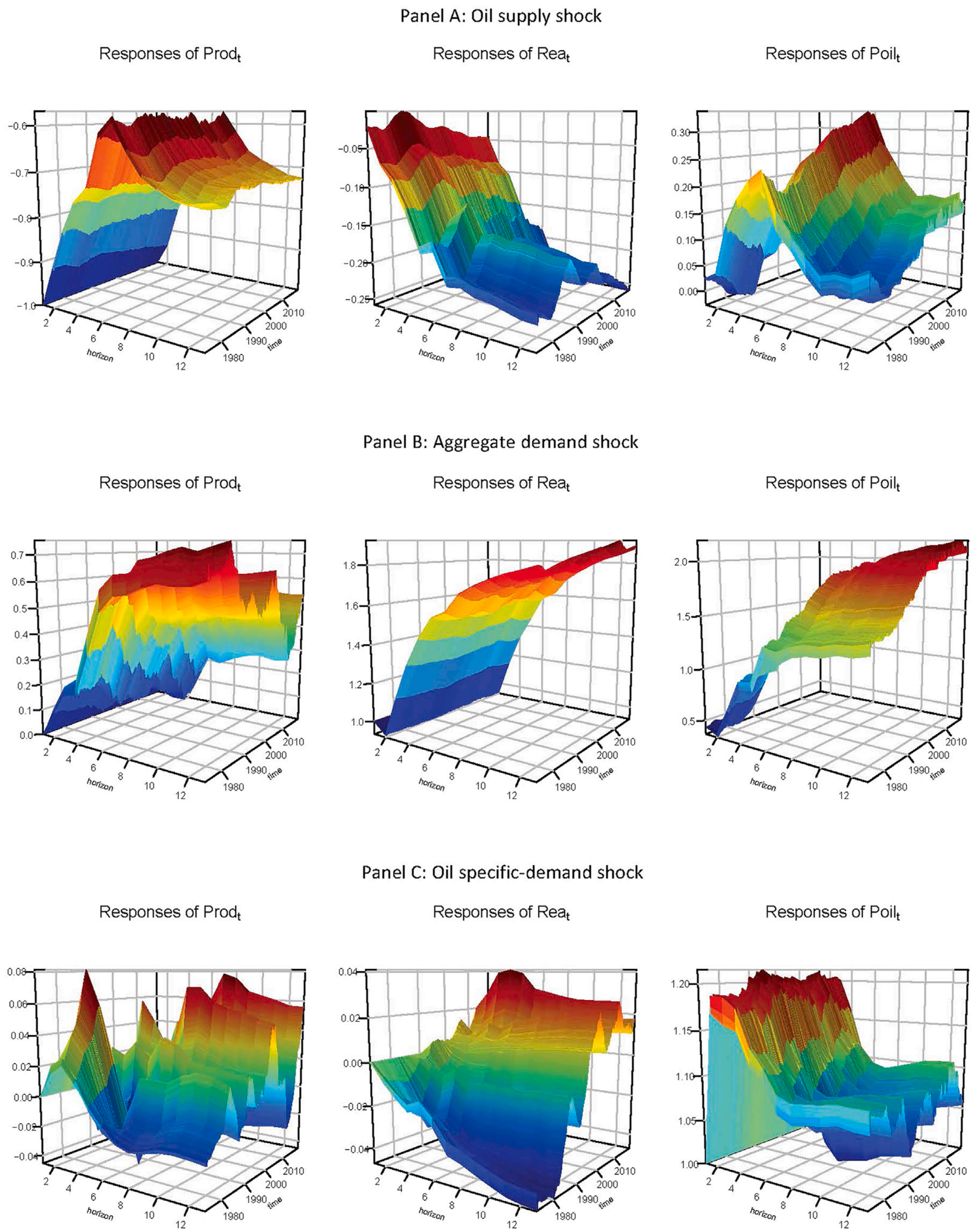

Fig. 2. Responses to structural shocks. Note: This Figure shows the 3D posterior median accumulated responses of endogenous variables to one unit shock for each structural shock over time (1973:08–2019:06). Panel A shows the responses to an unanticipated oil supply disruption (scaled to imply a 1% reduction in monthly world crude oil production), Panel B presents the impacts to an unexpected aggregate demand expansion (scaled to imply a 1% increase in global economic activity) and Panel C depicts the effects to an unexpected oil-specific demand increase (scaled to imply a 1% increase in real oil price that cannot be explained by the other two shocks).

once the mistake has been corrected. Finally, another measure is the one proposed by Ravazzolo and Vespignani (2020), which is based on the world steel production. However, this measure has been rarely used in the related literature.[14]

In our study, we consider the industrial production index of OECD countries + 6 non-OECD emerging countries (Brazil, China, India, Indonesia, Russia and South Africa) as our measure of global economic

[14] As Kilian and Zhou (2018) pointed out in their Table A.1, there are other different indicators of global economic activity based on real commodity price indices and qualitative indicators. However, the use of these indicators is very limited.

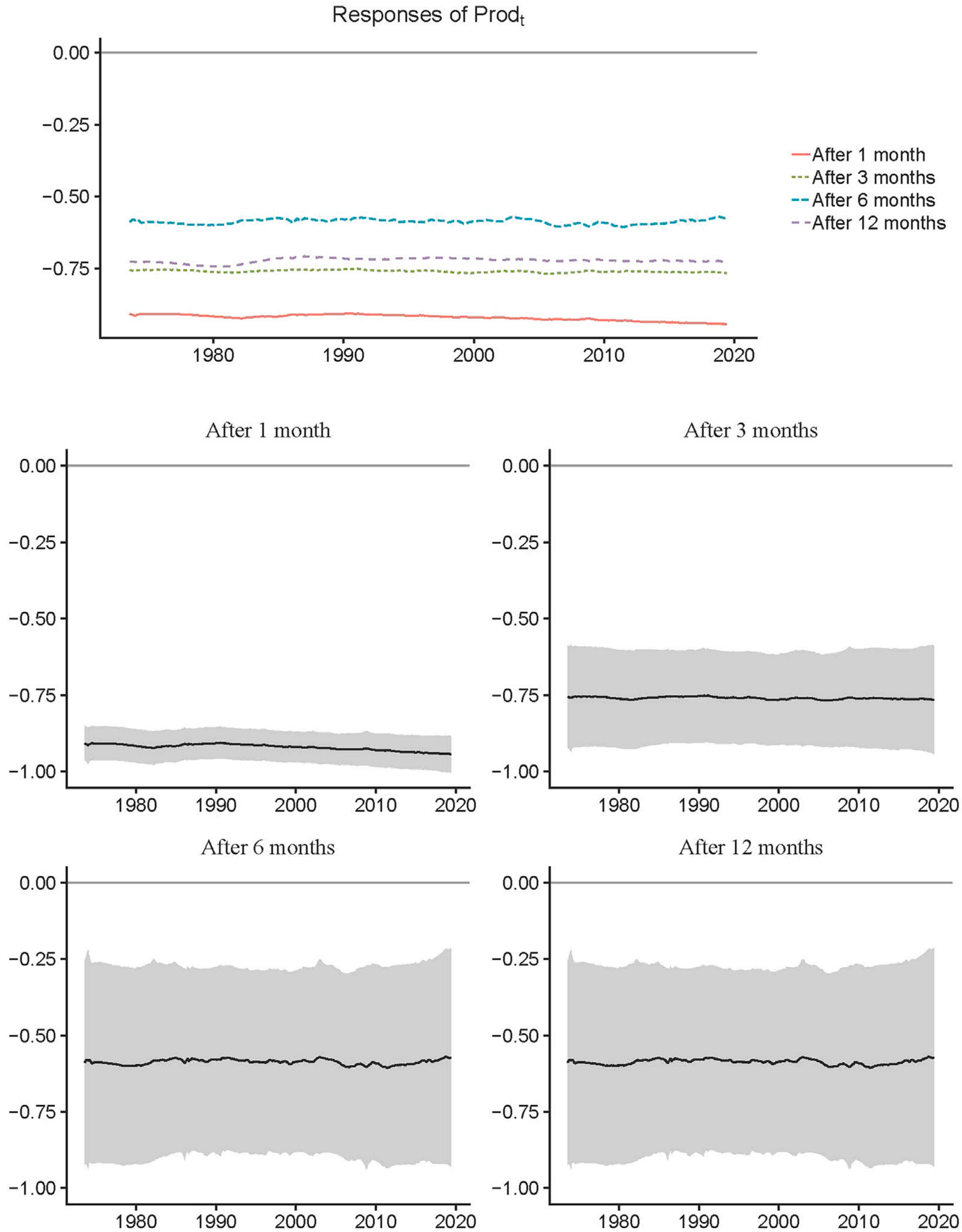

Fig. 3A. Responses of oil production to an oil supply shock. Note: This Figure shows the accumulated responses of world oil production to an unanticipated oil supply disruption (scaled to imply a 1% reduction in monthly world crude oil production) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

activity given that these economies represented more than 80% of world GDP in 2020.

Other variables used in our analysis are the world crude oil production, whose data are provided by the U.S. Energy Information Administration (see https://www.eia.gov/), and the real price of oil, which is obtained by deflating the nominal spot crude oil price (West Texas Intermediate, WTISPLC, downloaded from FRED) according to the U.S. CPI.[15,16]

3. Methodology

3.1. General description

This subsection closely follows the description offered by Primiceri (2005) and Del Negro and Primiceri (2015) to present the estimation of a TVP-VAR model. In particular, we consider the following n-variable

[15] It is common in the recent studies to calculate real commodity prices by deflating nominal ones according to U.S. CPI (see, for instance, IMF database, https://www.imf.org/-/media/Files/Research/CommodityPrices/Monthly/ChartsAUGUST.ashx) given that the IMF's index of the unit value of manufactured exports (MUV) is no longer available.

[16] Fig. A.1 in the Appendix shows the evolution of each variable in levels.

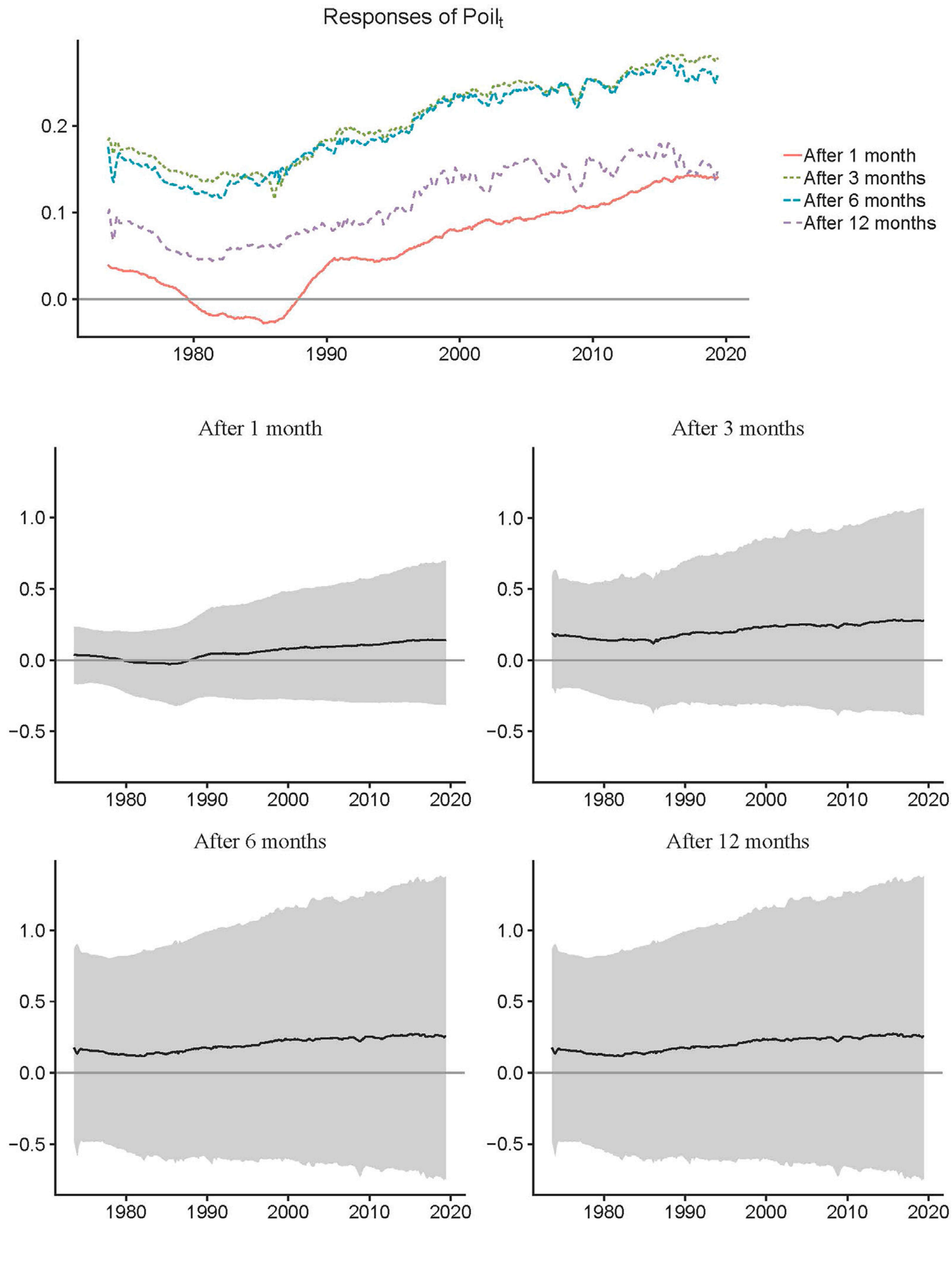

Fig. 3B. Responses of real oil price to an oil supply shock. Note: This Figure shows the accumulated responses of real oil price to an unanticipated oil supply disruption (scaled to imply a 1% reduction in monthly world crude oil production) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

p-order TVP-VAR model:

$$y_t = C_t + \sum_{j=1}^{p} \Theta_{j,t} y_{t-j} + u_t, \tag{1}$$

where y_t is an $(n \times 1)$ vector that contains the observed endogenous variables; C_t is an $(n \times 1)$ vector of time-varying (TV) coefficients that multiply constant terms; $\Theta_{1,t}, \Theta_{2,t}, \ldots, \Theta_{p,t}$ are $(n \times n)$ matrices of TV coefficients; and u_t is an $(n \times 1)$ vector of heteroscedastic errors with variance–covariance matrix Ψ_t.

The model can be rewritten as follows:

$$y_t = (I_n \otimes x_t')\beta_t + u_t, \tag{2}$$

where I_n is an n-dimensional identity matrix; $\otimes$ denotes the Kronecker product; $x_t' = \left[1, y_{t-1}', \ldots, y_{t-p}'\right]$ is the vector of $1 \times (1 + np)$ explanatory variables; and $\beta_t = vec(\boldsymbol{\Theta}_t)$ is the stacked vector of TV coefficients $\boldsymbol{\Theta}_t = \begin{pmatrix} C_t & \Theta_{1,t} & \ldots & \Theta_{p,t} \end{pmatrix}$.

As in Primiceri (2005), we consider the triangular reduction of Ψ_t:

$$A_t \Psi_t A_t' = \Sigma_t \Sigma_t', \tag{3}$$

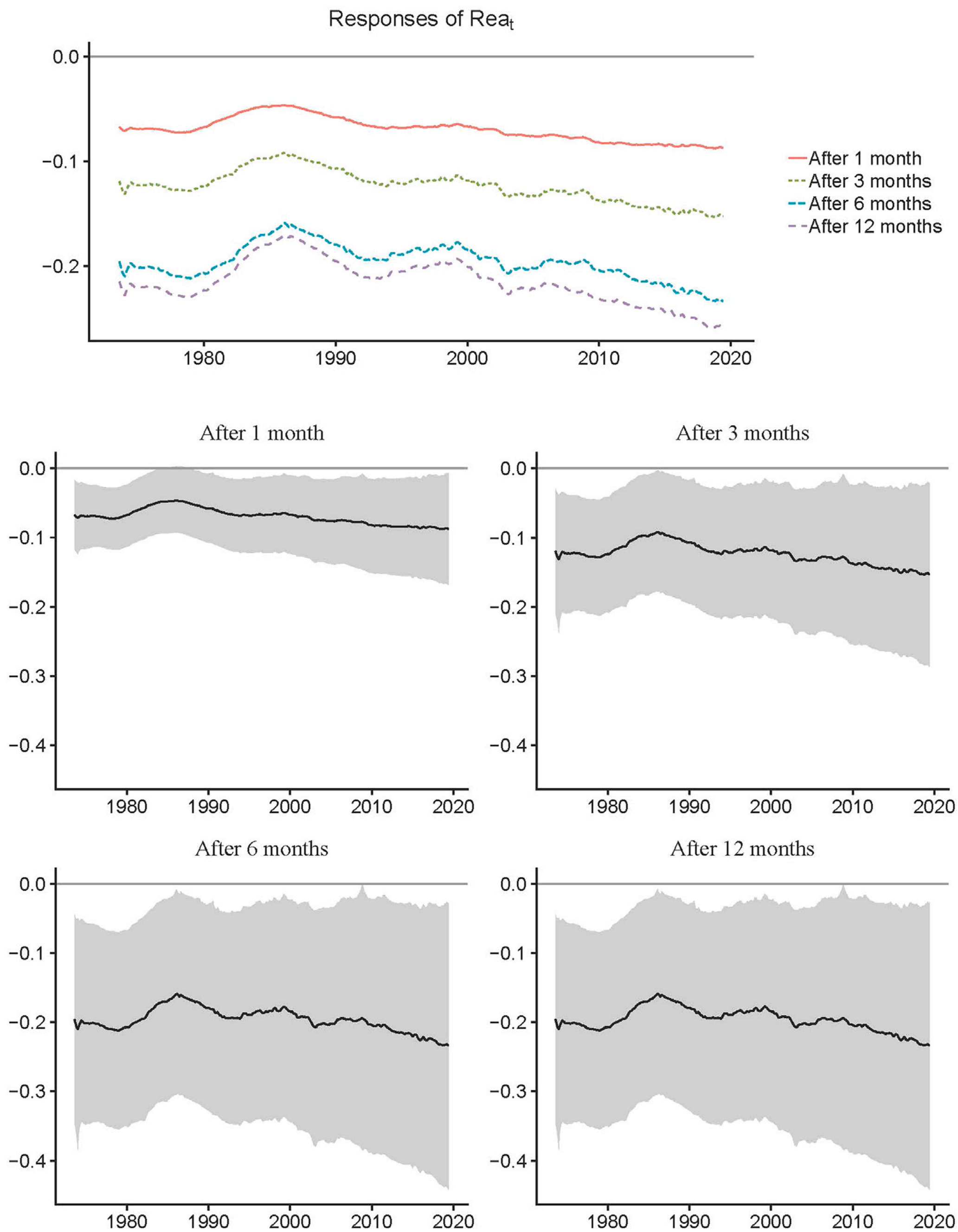

Fig. 3C. Responses of global economic activity to an oil supply shock. Note: This Figure shows the accumulated responses of global economic activity to an unanticipated oil supply disruption (scaled to imply a 1% reduction in monthly world crude oil production) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

with A_t being the lower triangular matrix with ones on the diagonal and Σ_t being the diagonal matrix with diagonal elements being TV error deviations:

$$A_t = \begin{bmatrix} 1 & 0 & \dots & 0 \\ a_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{n1,t} & \dots & a_{nn-1,t} & 1 \end{bmatrix} \qquad \Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \dots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_{n,t} \end{bmatrix}. \tag{4}$$

Therefore, the TVP-VAR model can be written as follows:

$$y_t = (I_n \otimes x_t')\beta_t + A_t^{-1}\Sigma_t \epsilon_t, \tag{5}$$

where ϵ_t has I_n as the variance–covariance matrix.

Let a_t be the vector of non-zero and non-one elements of the matrix A_t (stacked by rows), $a_t = (a_{21,t}, a_{31,t}, a_{32,t}, \dots, a_{n1,t}, \dots, a_{nn-1,t})'$.

The dynamics of the TV parameters is as follows:

$$\begin{aligned} \beta_t &= \beta_{t-1} + v_t \\ a_t &= a_{t-1} + \xi_t \end{aligned} \tag{6}$$

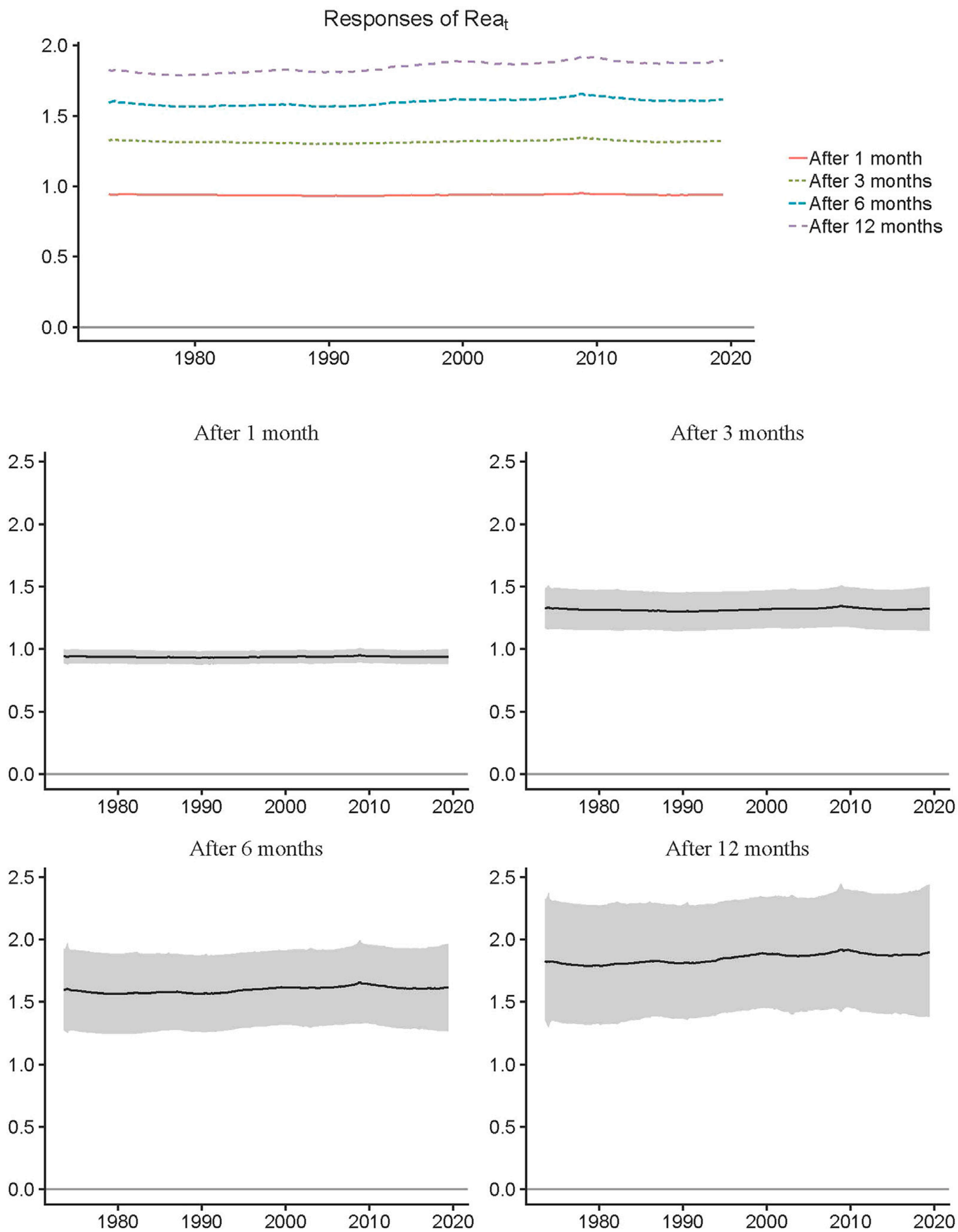

Fig. 4A. Responses of global economic activity to an aggregate demand shock. Note: This Figure shows the accumulated responses of global economic activity to an unexpected aggregate demand expansion (scaled to imply a 1% increase in global economic activity) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

$$\log \sigma_t = \log \sigma_{t-1} + \eta_t$$

where β_t, a_t and $\log \sigma_t$ describe the dynamics of the coefficients, the non-zero and non-one elements of matrix A_t, and the logarithm of the elements of diagonal matrix Σ_t, respectively.

The error terms in the model are assumed to be jointly normally distributed with variance–covariance matrix V:

$$V = Var \begin{pmatrix} \varepsilon_t \\ \upsilon_t \\ \xi_t \\ \eta_t \end{pmatrix} = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix}, \tag{7}$$

where Q, S and W are positive definite matrices. Moreover, S is block diagonal, with each block corresponding to the parameters of each separate equation.

The priors basically follow the same principles as in Primiceri (2005) and are summarized in Table 1.

The priors of Table 1 are used to perform Bayesian inference. It is used Markov Chain Monte Carlo (MCMC)[17] posterior simulation

[17] The algorithm MCMC 3 developed by Del Negro and Primiceri (2015) is considered.

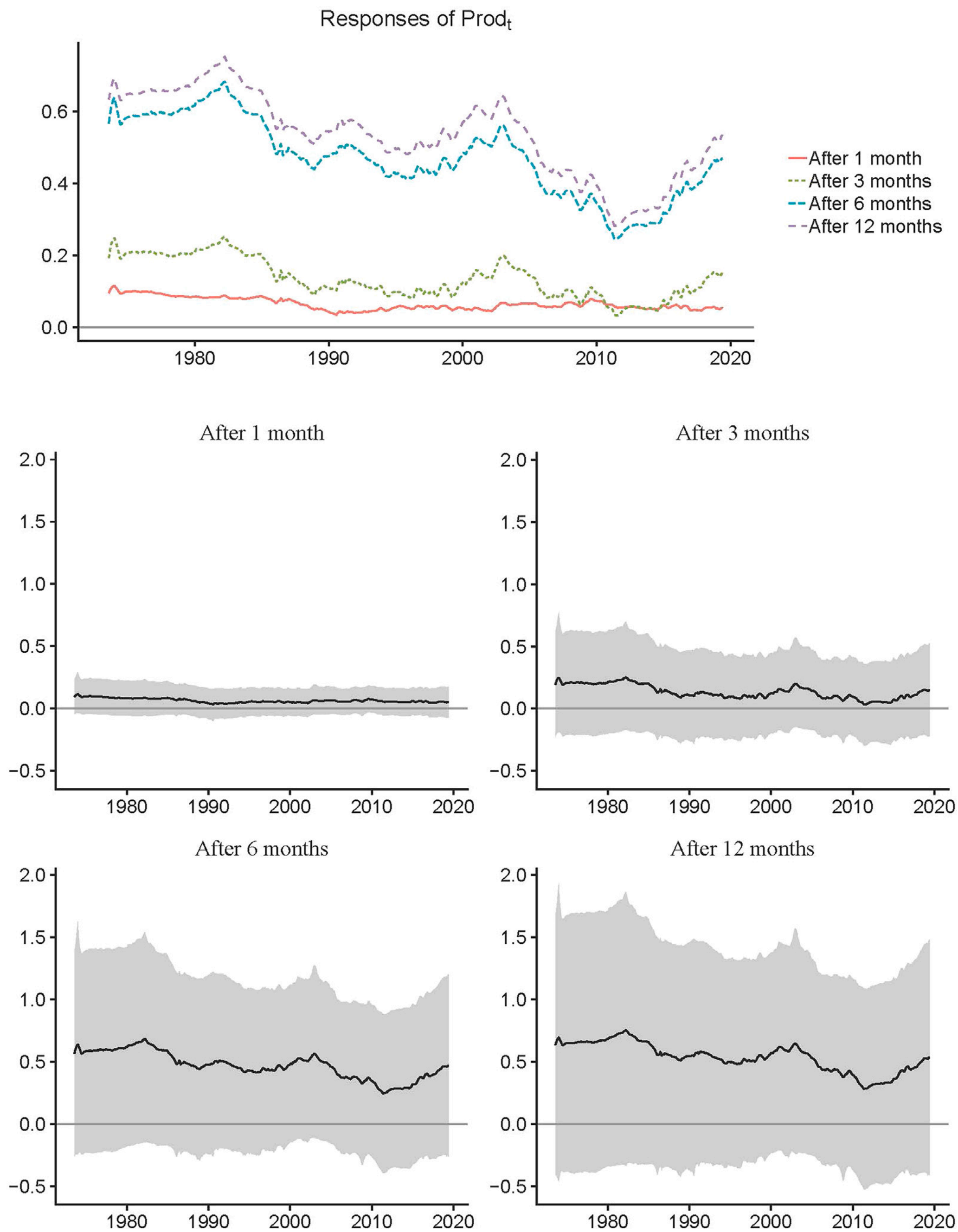

Fig. 4B. Responses of oil production to an aggregate demand shock. Note: This Figure shows the accumulated responses of world oil production to an unexpected aggregate demand expansion (scaled to imply a 1% increase in global economic activity) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

methods (Gibbs sampler) for the unobservable states[18] β^T, A^T, Σ^T and the hyperparameters of the variance–covariance matrix V. The Gibbs sampler entails the simulations based on 20,000 iterations, with the first 2000 being discarded as burn-in sample.

3.2. The specific model

We consider that y_t contains the following variables: (i) the first log differences of the world crude oil production, $\Delta prod_t$; (ii) the first log differences of the industrial production index of OECD countries + 6 non-OECD emerging countries, Δrea_t; and (iii) the first log differences of the real oil price, $\Delta poil_t$.[19]

Following Kilian (2009), we consider a recursively identified structural model of the form:

$$\begin{pmatrix} u_t^{\Delta prod} \\ u_t^{\Delta rea} \\ u_t^{\Delta poil} \end{pmatrix} = A_t^{-1}\Sigma_t \begin{pmatrix} \varepsilon_t^{\text{oil supply shock}} \\ \varepsilon_t^{\text{aggregate demand shock}} \\ \varepsilon_t^{\text{oil-specific demand shock}} \end{pmatrix}. \tag{8}$$

[18] β^T, A^T and Σ^T denote the entire path of parameters $\{\beta_t\}_{t=1}^T$, $\{A_t\}_{t=1}^T$ and $\{\Sigma_t\}_{t=1}^T$, respectively.

[19] The reported first log differences are multiplied by 100, so that its variations can be interpreted as percentage monthly changes.

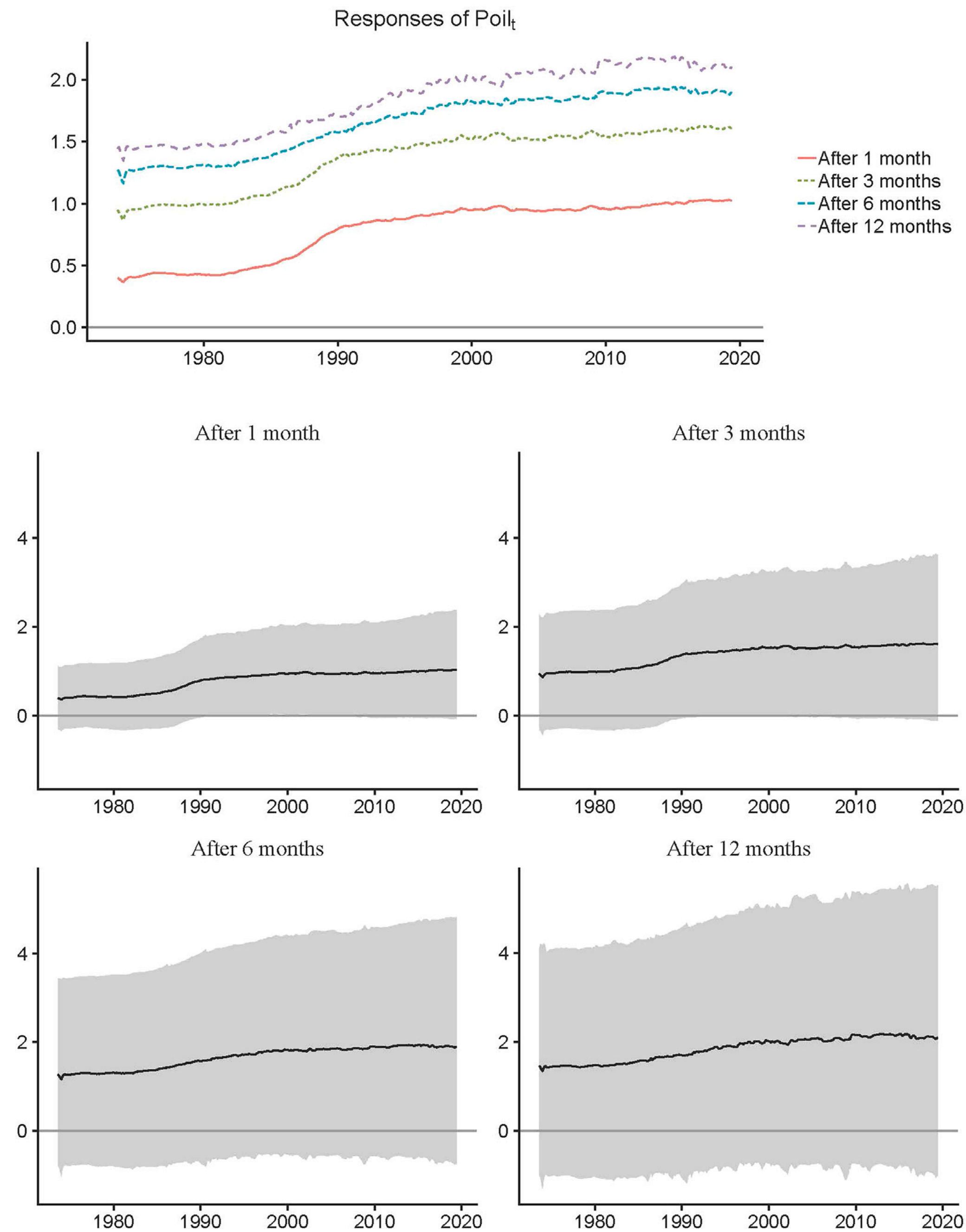

Fig. 4C. Responses of real oil price to an aggregate demand shock. Note: This Figure shows the accumulated responses of real oil price to an unexpected aggregate demand expansion (scaled to imply a 1% increase in global economic activity) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

We can identify three shocks occurred in the crude oil market: (i) oil supply shocks, which represent unexpected innovations to world crude oil production; (ii) aggregate demand shocks, which are determined by innovations to global economic activity; and (iii) oil-specific demand shocks, which come from innovations to the real oil price that cannot be explained by the other two shocks.

We estimate the TVP-VAR(6) model[20] for the common sample 1968:02–2019:06 by means of the Bayesian method described in the previous subsection in order to analyze how global economic activity reacts to the different shocks in the crude oil market.

4. Results

Fig. 1 presents the TV standard deviations of each structural shock for the period August 1973–June 2019 derived from the estimation of the TVP-VAR model.[21] While the top panel of Fig. 1 relates to oil supply shocks, the middle and bottom panels refer to aggregate demand shocks

[20] The choice of six lags is based on a strand of the literature on TVP-VAR models that includes 2 quarterly lags (Primiceri, 2005; Koop et al., 2009; and Liu and Morley, 2014; among others) or 6 monthly lags (Kang et al., 2015).

[21] Notice that the observations used in the training sample to establish the priors are discarded and six lags are included in the model.

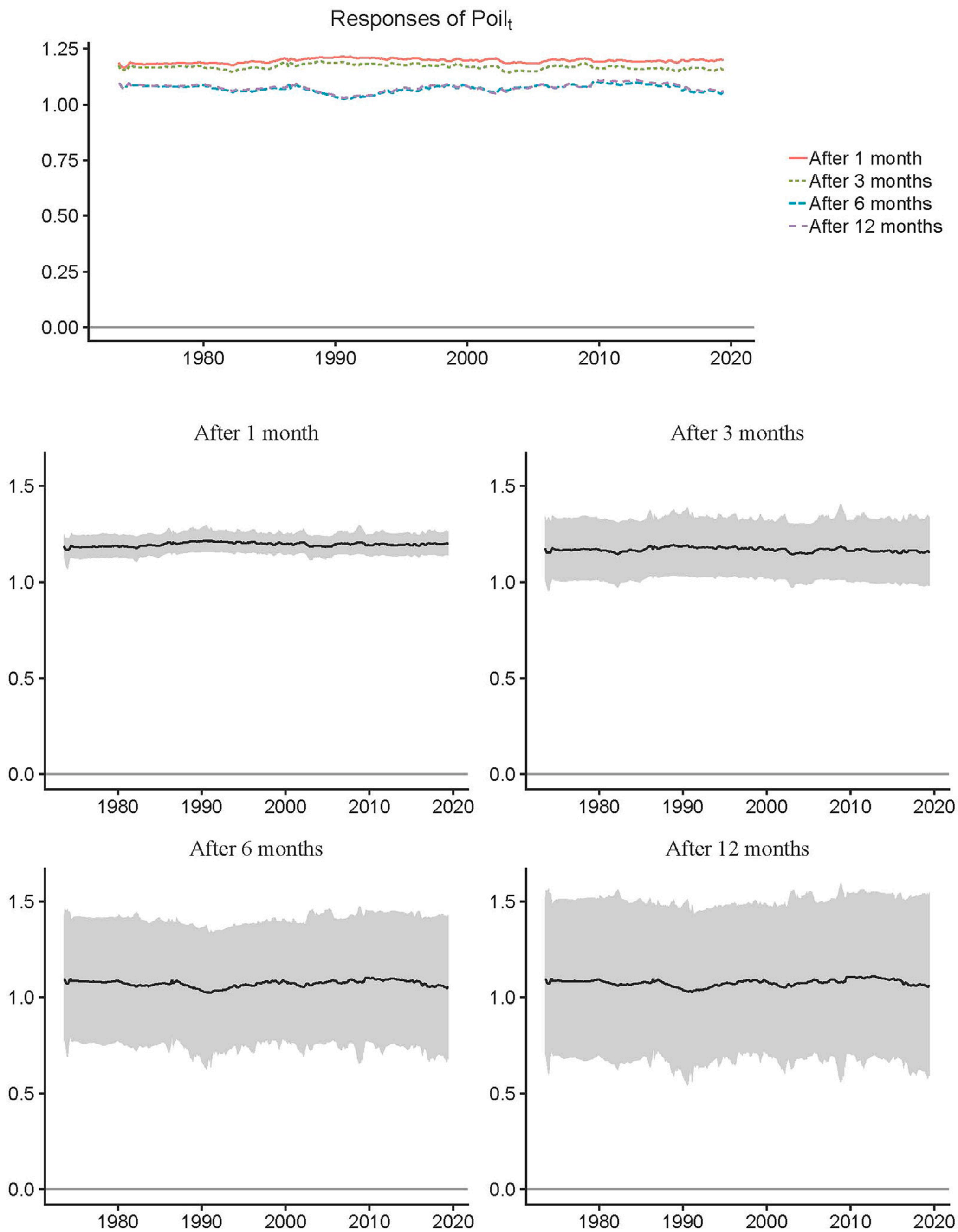

Fig. 5A. Responses of real oil price to an oil-specific demand shock. Note: This Figure shows the accumulated responses of real oil price to an unexpected oil-specific demand increase (scaled to imply a 1% increase in real oil price that cannot be explained by the other two shocks) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

and oil-specific demand shocks, respectively. It is observed the existence of several peaks in the evolution of standard deviations, which are related to both historical events in the crude oil market (Yom Kippur War, Iranian Revolution, Iran–Iraq War, crude oil market collapse, Gulf War, or introduction of fracking technique; among others) and movements in the world markets that generate economic and financial instabilities like those related to Asian financial crisis or global financial crisis.

Fig. 2 shows the three-dimensional (3D) plot of time-varying accumulated responses of each dependent variable to one unit shock for the three shocks occurred in the crude oil market for the period August 1973–June 2019.[22] Following Kilian (2009), we normalize all shocks such that an innovation tends to raise the real price of oil. Thus, Panel A shows the responses to an unanticipated oil supply disruption (scaled to imply a 1% reduction in monthly world crude oil production), Panel

[22] The accumulated responses reported are referred to the posterior median of accumulated structural impulse-response functions. Credible sets are not included in Fig. 2 to simplify the reading.

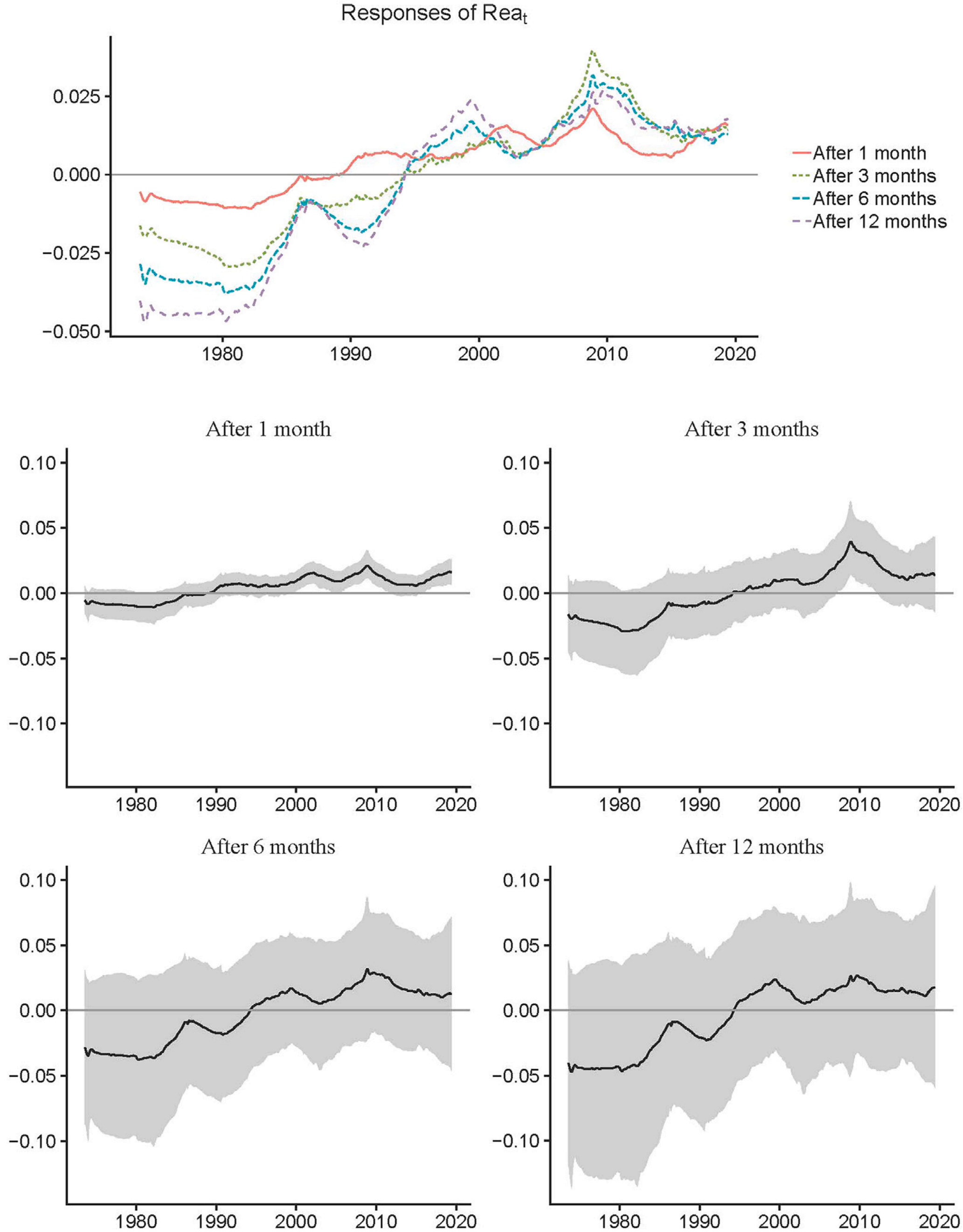

Fig. 5B. Responses of global economic activity to an oil-specific demand shock. Note: This Figure shows the accumulated responses of global economic activity to an unexpected oil-specific demand increase (scaled to imply a 1% increase in real oil price that cannot be explained by the other two shocks) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

B presents the impacts to an unexpected aggregate demand expansion (scaled to imply a 1% increase in global economic activity) and Panel C depicts the effects to an unexpected oil-specific demand increase (scaled to imply a 1% increase in real oil price that cannot be explained by the other two shocks).

It is observed that whereas an unanticipated oil supply disruption reduces oil production and global economic activity, it tends to raise the real price of oil. An unexpected aggregate expansion raises the three variables (i.e., oil production, global economic activity and real oil price). The response of oil production to an unexpected oil-specific demand increase considerably differs over time, with periods of hikes interspersed with periods of declines. Such a shock raises real oil price at any time period and tend to reduce global economic activity up to the 1990s and boost it after that decade.

Given that the 3D plots are generally not easy to read and interpret, Figs. 3A–5C display the evolution of the posterior median accumulated responses of the dependent variables to each of the three oil structural shocks after one, three, six and twelve months for the period August 1973–June 2019. The top panel of each Figure simply presents the median reactions, while the rest of panels in each Figure also include the

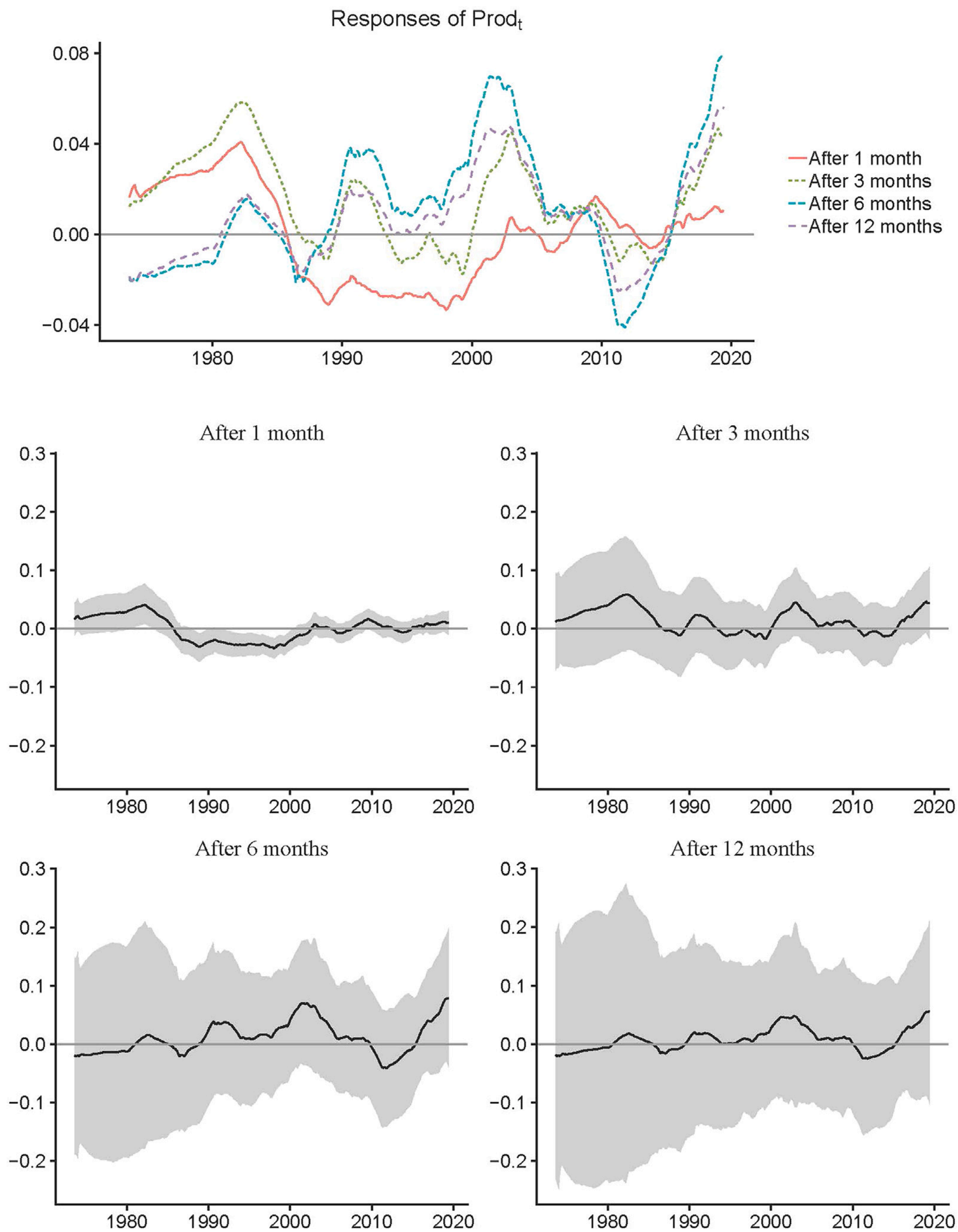

Fig. 5C. Responses of oil production to an oil-specific demand shock. Note: This Figure shows the accumulated responses of world oil production to an unexpected oil-specific demand increase (scaled to imply a 1% increase in real oil price that cannot be explained by the other two shocks) over time (1973:08–2019:06). The top panel presents the median responses one, three, six and twelve months after the shock on the same chart, while the other panels show both the median responses after one, three, six and twelve months and their 68% posterior credible sets.

68% posterior credible sets.[23] Unless otherwise noted, effects discussed refer to the median reactions.

Figs. 3A–3C present the effects of an unanticipated oil supply disruption. We observe that an unanticipated oil supply disruption considerably reduces world oil production, with zero not being within the credible sets (see Fig. 3A). However, there is a partial reversal of this decline after a year, which can be explained by the fact that the disruption of oil production in one region boosts the production in others (Kilian, 2009). Moreover, this disruption seems to exert upward pressure on the real price of oil, although zero is containing in the credible sets at all response horizons and at all time periods, suggesting a substantially negligible reaction (see Fig. 3B). As Kilian (2008) highlighted, the negligible response of oil price is in line with the fact that oil supply shocks have a reduced predictive power for oil price changes. In addition, the unexpected decline in world oil production

[23] It is worth mentioning that the posterior estimates do not rule out a negligible impact when credible sets include the zero line and that the narrower the credible sets, the more precisely the effects are estimated.

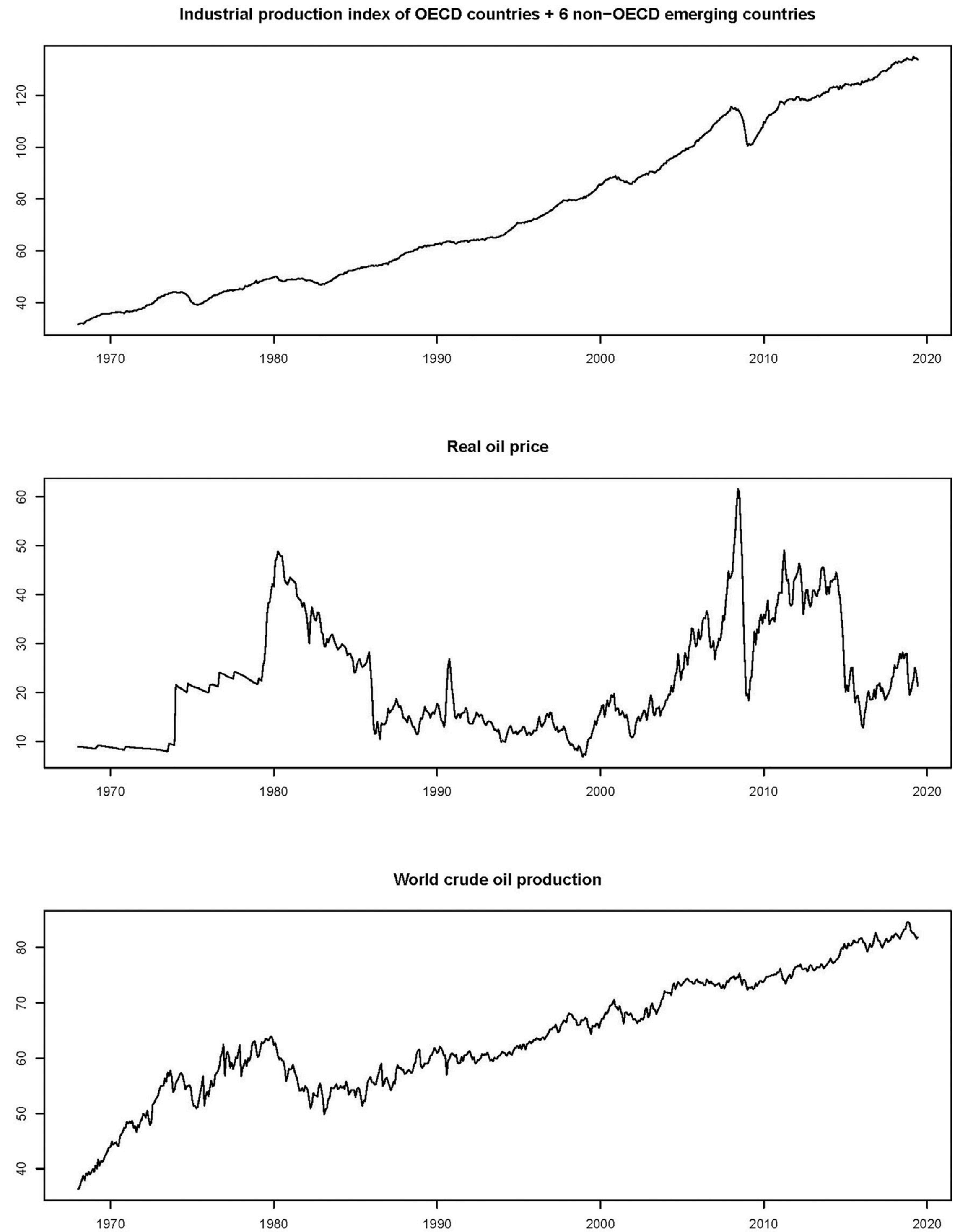

Fig. A.1. Evolution of variables (in levels). Note: This Figure shows the evolution of the level of each variable from 1968:01 to 2019:06.

meaningfully reduces global economic activity (see Fig. 3C), which is consistent with the findings of Baumeister and Hamilton (2019). The decline in global economic activity could be explained by the fact that world oil production shortfalls that tend to raise oil price[24] induce: (i) firms to lower output due to an increase in production costs (since crude oil is a basic input to production); (ii) consumers to reduce consumption of petroleum-related products (specifically, fuels and heating oil) due to their higher price; and (iii) consumers/producers to postpone their consumption/investment plans due to lower levels of current and expected income/benefits.

Figs. 4A–4C plot the responses to an unexpected aggregate demand expansion. This expansion raises global economic activity, with a persistent and relevant impact (see Fig. 4A), which is concordance with the results of Kilian (2009) and Baumeister and Hamilton (2019). As in the latter mentioned study, the aggregate demand expansion leads to

[24] Notice that we have normalized all shocks such that an innovation tends to increase the real price of oil.

an increase in both world oil production (see Fig. 4B) and real oil price (see Fig. 4C), although here zero is within the credible sets, suggesting that this increase is essentially negligible (in line with the results of Kilian, 2009, when two-standard error bands are considered).

Additionally, the responses reported in Figs. 3A–4C indicate that there were no considerable variations in the impact of oil supply and aggregate demand shocks over time. However, this is not the case when we observe the reactions of world oil production and global economic activity to an unexpected oil-specific demand increase (shown in Figs. 5A–5C), which change considerably over time.

Figs. 5A–5C show the effects of an unexpected oil-specific demand increase. The effect on real oil price is relevant, persistent and similar over time (with this similarity being expected since shocks have been scaled to imply a 1% increase in real oil price)(see Fig. 5A). However, the impact on global economic activity has changed over time (see Fig. 5B). While it was negative from the beginning of the 1970s up to the 1990s (with such an effect being mitigated since the crude oil market collapse in the mid-1980s), it became positive after the 1990s and was increasing until the beginning of the global financial crisis, where a peak was reached. Notice that zero is not within the credible sets only in the very short term and for some specific events, suggesting that a relevant effect at very short term for the shocks produced in the early 2000s, the global financial crisis and the shocks occurred in the last years of the 2010s.[25] It is worth mentioning that these Figures show the impacts of an increase, so if there has been a decrease, they should be interpreted with the opposite sign to that shown in the Figures. Thus, for instance, there was a decline in the real price of oil and a drop in global economic activity in the 2008–2009 financial crisis. Kilian (2009) found that an unanticipated oil market-specific demand increase was associated with a temporary increase in global economic activity, while Baumeister and Hamilton (2019) found a negligible rise in economic activity after an unexpected oil consumption demand increase.

The impact of an unanticipated oil-specific demand increase on world oil production has changed both over time and over the response horizon (see Fig. 5C), although the credible sets just do not include zero in the very short term.[26] There have been periods in which the effects one month after the shock were meaningfully positive (before the mid-1980s) and periods where the impacts were meaningfully negative (period between the mid-1980s and early 2000s).

5. Conclusions

The study of the impact of oil shocks on a measure of global economic activity has been scarce in the literature. Moreover, the existing literature on this topic has considered time-invariant parameter models and, therefore, has not taken into account the possibility that the response of global economic activity to oil shocks may differ over time.

This paper analyzes how global economic activity may respond differently to oil shocks over time. To do so, we consider a TVP-VAR model and we identify three shocks occurred in the crude oil market: oil supply shocks, aggregate demand shocks and oil-specific demand shocks.

Our findings indicate that an unanticipated oil supply disruption gives rise to a relevant decline in global economic activity at any period of time considered (1973:08–2019:06) and at any response horizon, with the decline not being considerably different over time. An unexpected aggregate demand expansion meaningfully fosters global economic activity at any period of time and at any response horizon. However, an unexpected oil-specific demand increase does not have a substantial effect on global economic activity in the medium- and long-term, although it does in the very short term for the shocks produced in the early 2000s, the global financial crisis and the shocks occurred in the last years of the 2010s.

Our results are in line with those of Baumeister and Hamilton (2019) who, using a time-invariant model, found that oil supply shocks reduce global economic activity, but oil consumption-demand shocks do not.

According to our results, investors and policy makers can expect an impact of upcoming oil supply and demand shocks on global economic activity to have a similar pattern to that seen in previous shocks. Thus, they should be able to anticipate the adverse (positive) effects on their business portfolios or on their domestic economies, respectively, and try to minimize (amplify) them with the appropriate decisions. The response similarity in time does not occur with the oil-specific demand shocks. Therefore, investors and policy makers must be cautious and adapt their decisions depending on the time when these shocks occur.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

See Fig. A.1.

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[25] The fact that the impact of an unexpected oil-specific demand increase on global economic activity is positive may have to do with the financialization of crude oil market. We thank one of the referees for suggestion this point. Among many others, UNCTAD (2012), Cheng and Xiong (2014), Bianchi et al. (2020) and Natoli (2021) analyze the financialization of commodity markets (including crude oil market).

[26] Kilian (2009) found a non-significant impact of an unanticipated oil-specific demand increase on world oil production.

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