

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Kim, Gil; Vera, David

Article

The effect of oil price fluctuation on the economy: What can we learn from alternative models?

Journal of Applied Economics

Provided in Cooperation with: University of CEMA, Buenos Aires

Suggested Citation: Kim, Gil; Vera, David (2022) : The effect of oil price fluctuation on the economy: What can we learn from alternative models?, Journal of Applied Economics, ISSN 1667-6726, Taylor & Francis, Abingdon, Vol. 25, Iss. 1, pp. 856-877, https://doi.org/10.1080/15140326.2022.2053940

This Version is available at: https://hdl.handle.net/10419/314190

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.



https://creativecommons.org/licenses/by/4.0/

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.









Journal of Applied Economics

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/recs20

The effect of oil price fluctuation on the economy: what can we learn from alternative models?

Gil Kim & David Vera

To cite this article: Gil Kim & David Vera (2022) The effect of oil price fluctuation on the economy: what can we learn from alternative models?, Journal of Applied Economics, 25:1, 856-877, DOI: 10.1080/15140326.2022.2053940

To link to this article: https://doi.org/10.1080/15140326.2022.2053940

© 2022 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



6

Published online: 07 Jun 2022.

ſ	
l	

Submit your article to this journal 🖸

Article views: 5971



View related articles

View Crossmark data 🗹



Citing articles: 3 View citing articles 🖸

APPLIED ECONOMETRICS

OPEN ACCESS Check for updates

Routledae

Taylor & Francis Group

The effect of oil price fluctuation on the economy: what can we learn from alternative models?

Gil Kim and David Vera

Department of Economics, Craig School of Business, California State University, Fresno, CA, USA

ABSTRACT

Following the exisiting literature, we present the most up-to-date estimates of oil shocks and the response of the U.S. economy. Regardless of model specifications, oil supply shocks have a negative effect on the U.S. real GDP, albeit the magnitude of responses is different across models. Aggregate demand shocks and oil-market specific shocks appear to have a positive effect on CPI, while there is little evidence of inflationary impact from the oil supply shocks. Overall, our results suggest that to evaluate the impact of an unexpected change on the price of oil on economic activity, identifying the source of the price of oil fluctuation might be one of the critical steps since the response of the GDP and CPI could vary depending on the source of the shocks.

ARTICLE HISTORY

Received 7 July 2021 Accepted 12 March 2022

KEYWORDS Oil shocks: oil prices: business fluctuations

1. Introduction

The price of oil has received significant attention as one of the main drivers of the fluctuation of major economic variables. A wide range of studies examine the causal relationship between the price of oil and other variables, such as the exchange rate, financial market assets, U.S. interest rate, aggregate output, and the price of goods and services (Ji, Shahzad, Bouri, and Suleman (2020)), Kilian and Zhou (2019), Shahzad, Bouri, Raza, and Roubaud (2019), Ready (2018), just to name a few). Given the wide range of studies on the oil price changes and their effects on different economic variables, the next natural step is to disentangle the different sources of the shocks that drive oil price changes and to clarify the link between these shocks and other related variables.

There are several strands of literature that attempt to identify the source of fluctuations in the oil price, whether it is an oil supply disruption, aggregate demand expansion, or other speculative channels that lead to an increase in demand for oil. Most of the earlier literature has considered the oil price fluctuations based on the movement of the supply side of the oil market (e.g., Hamilton (2003)). More recently, many studies have concluded that the aggregate demand side of the oil market can be a significant source of the fluctuations in the price of oil (e.g., Kilian (2008) and Kilian (2009)). For example, Kilian (2009) examines the sources of the price of oil fluctuation by considering the demand side shocks as well as the supply shocks in the oil market. Kilian (2009) triggered

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/ licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited

CONTACT David Vera 🖾 dvera@csufresno.edu 🖃 Department of Economics, California State University, 5245 N. Backer Avenue, M/S PB20, Fresno, CA 93740-8001, USA

^{© 2022} The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

a lot of additional relevant literature that studied the different sources of oil shocks based on various identification assumptions and model specifications. Kilian and Murphy (2014) extended their model by taking into account the global crude oil inventory series to explicitly capture the speculative demand for oil as well as the flow of demand and supply of the oil market.

This paper contributes to the literature by examining the influence of real oil price fluctuations on U.S. output and the price level under alternative identification specifications. We attempt to answer the following research questions: 1) how different is the response of U.S. GDP to alternative sources of oil shocks?, 2) can we find a consensus on the effects of the different shocks – not only supply shocks but also aggregate demand as well as speculative oil market shocks – on U.S. real GDP and the price level (CPI) across the different methodologies?, and 3) if the responses of real GDP or the price level differ depending on the methodologies applied, can we explain the cause of the difference?

The empirical results of this paper can be summarized as follows. When looking at the response of U.S. real GDP, our findings show that, as stated in the literature, oil supply shocks matter; we find that regardless of the model, oil supply shocks tend to have a negative effect on U.S. real GDP. When the source of the oil price change is aggregate demand shocks, the predicted effect on U.S. real GDP in two of the specifications (Kilian, 2009; Kilian & Murphy, 2014), although initially positive, turns negative on longer horizons, while the effect on U.S. real GDP is consistently positive under the third specification (Baumeister & Hamilton, 2019). In any case, when the changes in oil price are due to aggregate demand shocks, these appear to have a substantial effect on the U.S. real GDP under all specifications. We also find evidence that oil-market specific demand shocks (e.g., speculative demand shocks) can also affect the U.S. GDP. In addition, when the source of oil price changes is either aggregate demand shocks or oil-market specific shocks, these appear to have a positive effect on CPI, while there is little evidence of inflationary impact from the oil supply shocks. The results hold for all different specifications and for different sample periods.

Our paper is organized as follows. Section 2 presents the related literature on the link between oil price and other economic variables, and Section 3 and 4 describe the data and methodologies we used to analyze the source of fluctuations in the real price of oil and the effects of these fluctuations on the U.S. macroeconomy. Section 5 presents the results of the response of the oil market and the response of the U.S. GDP and CPI to the different shocks. Section 6 discusses the findings from a robustness check of alternative measures of global economic activity. Section 7 summarizes and concludes.

2. Literature review

A wide range of studies examine the causal relationship between the price of oil and the other variables, for instance, recent literature examines the channel between the change in oil price and the fluctuation of the exchange rate. For example, Kilian and Zhou (2019) examine the causal relationship between the change in the oil price and the values of the U.S. dollar and U.S. real interest rate while taking into account the different sources of the oil shocks. They find that the change in the U.S. dollar can be one of the major sources of the change in the oil price. For instance, the dollar depreciation in the early 1980s may have caused a higher demand for oil, which led to the increase in the price of oil. On the

other hand, Ji et al. (2020) study the other direction of causality for the price of oil and exchange rate in net oil importers and exporters with the methodological combination between the SVAR and the connectedness measure by Diebold and Yilmaz (2014). They find that the effects of oil supply shocks have a larger depreciating influence on the exchange rate in oil exporter countries, while the effects of aggregate demand and the oil-specific demand shock lead to an appreciation in the exchange rate market returns.

As a related topic on the effect of oil price on the financial market, Shahzad et al. (2019) examines the impacts of different sources of the oil market on economic policy uncertainty, stock market uncertainty, as well as treasure rates. By using the economic policy uncertainty (EPU) index by Baker et al., (2016) and VIX (Chicago Board of Trade Volatility Index) for stock market uncertainty and taking into account the positive and negative demand and supply oil shocks, they conclude that while the supply of oil shocks is the main source of the oil market for the change in the treasury rates, the demand shocks are the main drivers of the uncertainties – economic policy uncertainty and stock market uncertainty. They also find that the response of the investors' sentiment on the demand and supply shocks are asymmetric based on the sign of the shocks – depending on the sign of the shocks the size of the response of investors' sentiments are not the same.

Ready (2018) also examines the correlation between oil prices and stock market returns with a different approach. By using the information in asset prices, he identifies oil price changes driven by the demand and supply shocks separately. He develops the simple model of oil production at the firm level, which views oil as a depletable resource. Then, he develops SVAR model with an index of oil-producing firms (World Integrated Oil and Gas Producer Index for large publicly traded oil-producing firms), a measure of oil price changes (the 1-month return on the second nearest maturity NYMEX Crude-Light Sweet Oil contract) and a proxy for changes in expected returns (Aggregate U.S. stock market data) to construct the series of supply and demand shocks. The results support that the response of the U.S. and world stock prices are significant to both oil supply and demand shocks, while it shows the low correlations with aggregate changes in the price of oil.

On the other hand, the importance of identifying the sources of oil price fluctuation and their effects on economic activity has also been discussed in the literature. In the earlier literature, the importance of the effect of oil supply shocks based on global crude oil production on the economy than any other decomposed oil shocks has been emphasized. (Hamilton, 2003) Theoretically, the negative oil supply shocks can lead to the higher cost of production and the costly reallocation of the industries from the heavy energy consumption or production industries to less energy-consuming industries. (Hamilton (1988), Davis and Haltiwanger (2001))

There are studies that argue that the oil supply shocks may not be the only channel of the fluctuation of the oil price. For example, Kilian (2009) addresses the importance of disentangling the different sources of oil price shocks. Relying on a new measure of monthly real economic activity, Kilian (2009) identifies three different shocks (oil supply shocks, aggregate demand shocks, and oil-market specific demand shocks) in the SVAR. Kilian (2009) concludes that the aggregate demand shock is the main driver of oil price fluctuations. Kilian and Murphy (2014) develop an SVAR model with the construction of inventory data to capture the speculative demand for oil as well as shocks to flow demand and flow supply.

In the light of these various attempts to disentangle the different sources of oil shocks, one of our value-added contributions to the literature is that by using three alternative methods, we provide more general results on the economic fluctuations and responses of economic output and price level to the changes in the price of oil.

To examine the effects of different oil structural shocks on U.S. economic activity, we first estimate the different oil shocks under the three different methodologies of Kilian (2009), Kilian and Murphy (2014), and Baumeister and Hamilton (2019), which are the most leading methodologies in the literature. Then, we evaluate how the U.S. economy, with particular emphasis on the real GDP and CPI, responds to the different shocks by adopting Kilian (2009)'s work. In our analysis, for all model specifications, we extend our data to the end of 2017 and utilize the most updated data available. By employing three main identification specifications from the literature, we are able to confirm how the estimated responses of the U.S. output and price are different across the methodologies. Besides, analyzing two sample periods (1976-2008 and 1976-2017) permits a direct comparison of the local responses between pre-2008 and through-2017. By doing so, we can identify the changes in the responses of the U.S. economy to the oil price fluctuations due to any structural changes since 2008.¹ We also conduct robustness tests that address some of the debate in the literature on the use of the global economic activity index. We provide results based on an alternative variable to the measure of global economic activity for Kilian (2009) and Kilian and Murphy (2014) methodologies as well as Baumeister and Hamilton (2019).

3. Data

To implement the methodologies from Kilian (2009; hereafter K09), Kilian and Murphy (2014; hereafter KM14), and Baumeister and Hamilton (2019; hereafter BH19), we construct our data from the original data sources cited in their respective articles. We use monthly data from 1976 to the end of 2017 for all three alternative methodologies. For the crude oil market, depending on the modeling approach, we collect three or four variables.

To model the market for crude oil, we use the global crude oil production, a measure of global economic activity, the real price of oil, and the proxy for world crude oil inventories. The raw data for global oil production come from the *International Energy Statistics Data Browser*, published by the Energy Information Agency (EIA).² Global crude oil production includes lease condensates but excludes natural gas plant liquids as in Kilian (2009). We estimate the percentage change of oil production as the log differences of the world crude oil production. For a measure of global economic activity, we employ the most recent revised version

¹There are many studies that support structural changes since the financial crisis in 2008–2009. Also, the cost-effective drilling technology since 2008 helped to increase the annual production in the U.S. More details can be found from: https://www.eia.gov/energyexplained/oil-and-petroleum-products/where-our-oil-comes-from.php

²International petroleum (formerly Section 11 in MER) has been removed from the Monthly Energy Review (MER). Data for "Crude Oil including Lease Condensate" is now under EIA's International Energy Statistics data browser (https://www. eia.gov/opendata/qb.php?category=2134979 sdid = INTL.57-1-WORL-TBPD.M).

of "the index of global real economic activity" developed and modified by Kilian (2019) in K09 and KM14 specifications.³ We use the change in the log of the world industrial production index that includes industrial production for OECD and six major non-OECD member economies (Brazil, China, India, Indonesia, the Russian Federation, and South Africa) to capture the global economic activity in BH19 specification.⁴ We obtained the series of the real oil price, the refiner's acquisition cost for imported crude oil from the EIA.⁵ We first deflate it with U.S. CPI (CPIAUCSL), then transform it into the natural log, and remove the mean. The CPI series can be obtained from the St. Louis Fed FRED database.⁶

For the inventories series in KM14 and BH19, we follow the original papers' instruction. Due to lack of data on world crude oil inventories, KM14 used the total U.S. crude oil inventories series multiplied by the ratio of OECD petroleum stocks over U.S. petroleum stocks as a proxy of the world inventory data. The details of the data are as follows. The raw data of the monthly total U.S. crude oil inventory series come from the *Monthly Energy Review* (MER), published by the Energy Information Agency (EIA).⁷ We use the series labeled as "*Crude Oil Stocks, Total*" in Column D in "Table 3.4 Petroleum Stocks". The raw data of OECD petroleum stocks and the monthly data for the U.S. petroleum stocks come from the EIA database.⁸ The ratio of OECD petroleum stocks over U.S. petroleum stocks ranges from 2.23 to 2.61 in our sample from 1976:2 to 2017:12 and it is consistent with the ratio in KM14. Following the literature, we use the world inventory proxy series as the change in levels for KM14, and the change in OECD crude oil inventories as a percent of the previous month's world production for BH19.⁹

To examine the effect of oil price shocks on the U.S macroeconomy, as in Kilian (2009), we collect the U.S. real GDP and CPI series from the FRED database of the Federal Reserve Bank of St. Louis.¹⁰

³The monthly global real economic activity index based on dry cargo single voyage ocean freight rates, which has been developed in Kilian (2009) and recently revised and updated in Kilian (2019). The most updated Kilian's economic activity data can be obtained from the Federal Reserve Bank of Dallas at https://www.dallasfed.org/research/igrea

⁴The most updated data can be obtained at Hamilton's website (https://econweb.ucsd.edu/ jhamilto/pub_metrics) ⁵The original data,"U.S. Crude Oil Imported Acquisition Cost by Refiners", can be found from the Refiner Acquisition Cost

of Crude Oil, in EIA (https://www.eia.gov/dnav/pet/pet_pri_rac2_dcu_nus_m.htm)

⁶The CPI series (CPIAUCSL) can be found at https://fred.stlouisfed.org/series/CPIAUCSL.

⁷The raw data for the total U.S. crude oil inventories series comes from MER ((https: //www.eia.gov/totalenergy/data/ monthly/#crude)) "Table 3.4 Petroleum Stocks" located in "Stocks" under "Petroleum" Data Categories. More details can be found from Kilian and Murphy (2014) and Kilian (2017)

⁸We use the "Petroleum Stocks Total OECD End of Period Monthly" series (Series ID: TOTAL.PAPSPOC.M) for the OECD petroleum stocks. The data (file name: Petroleum_Stocks_Total_OECD_End_of_Period_Monthly.csv) is available through the following link as of July 2018. https://www.eia.gov/opendata/qb.php?category=711311. We extrapolate the missing data as the way indicated in Kilian and Murphy (2014). Please refer to footnote 7 in Kilian and Murphy (2014) for the details. Details are available upon request. For U.S. petroleum stocks, "Petroleum Stocks, United States, End of Period, Monthly (series ID:TOTAL.PAPPU.S.M)" series can be found from EIA Data Sets > Total Energy > Petroleum > Petroleum Stocks > Petroleum Stocks, United States, End of Period, Monthly (Million Barrels) (https://www.eia.gov/opendata/qb.php?category=711261)

⁹There are several reasons why Kilian and Murphy (2014) prefer the change in level over the percentage change for the global crude oil inventories series. 1) While the change in level of global crude oil inventories appears to be covariance stationary, the percentage change for the global crude oil inventories series does not. 2) For the oil demand elasticity calculation, they found that the change in level of global crude oil inventories is more reasonable than otherwise. For more details, please refer to page 457 in Kilian and Murphy (2014).

¹⁰The Real GDP series (GDPC1) and the CPI series (CPIAUCSL) can be accessed at https://fred.stlouisfed.org.

4. Methodology

4.1. Kilian (2009)

Consider a vector $z_t = (\Delta prod_t, rea_t, rpo_t)'$ where $\Delta prod_t$ is the percentage change in global crude oil production, rea_t is the index of real economic activity updated in Kilian (2019), and rpo_t is the real price of oil. rpo_t series is in logs. We use monthly data from 1976 to the end of 2017. The SVAR representation can be written as follows:

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \epsilon_t$$
 and $e_t = A_0^{-1} \epsilon_t$ (1)

where ε_t represents a vector of serially and mutually uncorrelated structural innovations, A_0^{-1} has a recursive structure identification, and e_t is the reduced-form errors. In detail, e_t can be represented as follows:

$$\mathbf{e}_{t} \equiv \begin{pmatrix} \mathbf{e}_{t}^{\Delta \text{prod}} \\ \mathbf{e}_{t}^{\text{rea}} \\ \mathbf{e}_{t}^{\text{rpo}} \\ \mathbf{e}_{t}^{\text{rpo}} \end{pmatrix} = \begin{bmatrix} \mathbf{a}_{11} & \mathbf{0} & \mathbf{0} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \mathbf{0} \\ \mathbf{a}_{31} & \mathbf{a}_{32} & \mathbf{a}_{33} \end{bmatrix} \begin{pmatrix} \in_{t}^{\text{oil supply shock}} \\ \in_{t}^{\text{aggregate demand shock}} \\ \in_{t}^{\text{oil-market specific demand shock}} \\ \in_{t}^{\text{oil-market specific demand shock}} \end{pmatrix}$$

By placing the global oil production at the top of the matrix, the global oil production does have a contemporaneous response to the oil supply shocks but not to other shocks, such as the aggregate demand shocks and oil-market specific shocks. The real global economic activity which represents the demand for all industrial commodities instead of the demand for all goods and services responds to both oil supply shocks and the aggregate demand shocks contemporaneously and it is influenced by the oil-market specific demand shocks with lags. By placing the real price of oil at the bottom of the matrix, the real price of oil is assumed to respond contemporaneously to all three structural shocks.

4.2. Kilian and Murphy (2014)

KM14 incorporates the inventory proxy for global crude oil inventories to capture the speculative oil-market specific demand shocks.

The structural vector autoregression model can be represented as follows.

$$\beta_0 \mathbf{y}_t = \sum_{i=1}^{24} \beta_i \mathbf{y}_{t-i} + \boldsymbol{\epsilon}_t \tag{2}$$

where y_t consists of four endogenous variables: the percentage change in global crude oil production, the index of real economic activity, the change in global crude oil inventories above the ground, and the log of the real price of oil. \in_t is the vector of orthogonal structural innovations with the four structural shocks. The first shock is defined as an unanticipated oil supply shock (referred as "flow supply shock" in the original paper), and the second shock is the aggregate demand shock (referred as "flow demand shock"), the third shock is the speculative demand shock. We follow the original paper by removing seasonal variation by including seasonal dummies in the VAR model.

862 🕒 G. KIM AND D. VERA

	Flow supply shock	Flow demand shock	Speculative demand shock
Oil production	-	+	+
Real activity	-	+	-
Real price of oil	+	+	+
Inventories			+

Lot in Sight Council of the part is the stand that phy (Lot in	Table	1. Sign	restrictions	on impac	t responses i	n SVAR	, Kilian	and Mur	phy	y (2014	4).
--	-------	---------	--------------	----------	---------------	--------	----------	---------	-----	---------	-----

To distinguish the speculative demand shock from the oil supply shock and aggregate demand shock, KM14 imposes four sets of identifying restrictions on the SVAR model as follows:

• Imposing the impact sign restrictions: Based on economic theory, the following restrictions are stored. The global crude oil production and the global real economic activity decrease in response to the unanticipated flow supply shocks, but the real price of oil increases to the shock. All three oil market variables, the global crude oil production, global real activity, and real price of oil, increase in response to the flow demand shocks. No sign restriction is imposed on the response of inventories to both flow supply and flow demand shocks. Lastly, the global oil production, the real price of oil, and the global oil inventories increase in response to the speculative demand shock, while the global real activity decreases. The summary of the sign restrictions is in Table 1.

• Imposing an upper bound on the impact price elasticity of oil supply: Since the literature suggests that the short-run price elasticity of oil supply is close to zero, if not effectively zero, KM14 imposes an upper bound of 0.0258 on the short-run price elasticity of oil supply in the baseline model. This restriction will allow the model to have the inelastic short-run supply curve, steep but not exactly vertical (see Kilian & Murphy, 2012).¹¹

• KM14 assumed that the impact price elasticity of oil demand is lower than the long-run elasticity of oil demand.¹²

• Additional dynamic sign restrictions are imposed on the oil supply shocks. The responses of the oil production and global real economic activity to an unanticipated flow supply shock must be negative for at least 1 year, while the response of the oil price to the same shock must be positive. No additional sign restrictions are imposed to either the aggregate demand shock or the specific oil market demand shocks.

4.3. Baumeister and Hamilton (2019)

BH19 developed a model with incomplete identification to relax the strong assumptions that the traditional vector autoregression can have. They also point out the possibility of considerable error in measuring world inventories of oil. To solve this issue, they generalize their structural vector autoregression by allowing for the measurement error in the global oil inventories. The baseline model can be represented as follows:

$$B_0 X_t = \sum_{i=1}^{12} B_i X_{t-i} + \epsilon_t$$
(3)

¹¹More work with a bound of 0.04 can be found in Zhou (2020).

¹²More discussions on the impact price elasticity of oil demand can be found in Sweeney (1984) and Hausman and Newey (1995).

JOURNAL OF APPLIED ECONOMICS 😣 863

$$\mathbf{X}_{t} = [q_{t}, y_{t}, p_{t}, \Delta i_{t}]', B_{0} = \begin{bmatrix} 1 & 0 & -\alpha_{qp} & 0\\ 0 & 1 & -\alpha_{yp} & 0\\ 1 & -\beta_{qy} & -\beta_{qp} & -\chi^{-1}\\ -\psi_{1} & -\psi_{2} & -\psi_{3} & 1 \end{bmatrix}, \varepsilon_{t} = \begin{bmatrix} \varepsilon_{1t}^{*} \\ \varepsilon_{2t}^{*} \\ \varepsilon_{3t}^{*} - \chi^{-1} \mathbf{e}_{t} \\ \chi \varepsilon_{4t}^{*} + \mathbf{e}_{t} \end{bmatrix}$$

where X_t consists of four endogenous variables; q_t is the monthly growth rate of global crude oil production, y_t is the world industrial production index, p_t is the real price of oil, Δi_t is the change in oil inventories as a percentage of the previous month's world oil production, and this is considered as imperfect observation since no good data on global oil inventories exist in the literature. The equation for Δi_t can be written as below.¹³

$$\Delta i_t = \chi \Delta i_t^* + e_t$$
 with $\chi < 1$

where η is a parameter representing the fact that OECD inventories, Δi_t^* , are only a fraction of the world inventories. e_t is the measurement error, with the assumption of serially uncorrelated and uncorrelated with the structural shocks. To let \in_t be as uncorrelated structural shocks, the additional conditions have been imposed to the system of equation (3).¹⁴ One thing that is important to point out is that the information of pre-1973 has been used to construct priors for their model.¹⁵

4.4. Local impulse response to the oil shocks by Kilian (2009)

As a next step, we proceed to estimate the effect of structural shocks on the U.S. local economy. Following K09, the monthly decomposed structural shocks are averaged for each quarter to be transformed into the quarterly data. ζ is the averaged structural innovations for the quarter.

$$\hat{\zeta}_{jt} {=} \frac{1}{3} {\sum_{i=1}^{3} \hat{\epsilon}_{j,t,i}}, \quad j=1,2,3$$

According to K09, there is no feedback in the same quarter from the U.S. GDP growth (Δy_t) and inflation (π_t) to the structural oil shocks, and the VAR can be written as follows:

$$\Delta y_t = \alpha_j + \sum_{i=0}^{12} \phi_{ji} \hat{\zeta}_{jt-i} + u_{jt}, \quad j = 1, 2, 3$$
(4)

$$\pi_t = \delta_j + \sum_{i=0}^{12} \psi_{ji} \hat{\zeta}_{jt-i} + \nu_{jt}, \quad j = 1, 2, 3$$
(5)

¹³BH19 describes the reasons why the change in global oil inventories data is imperfect observation. The errors of the estimate of global oil inventories could be due to 1) no data on OECD crude oil inventories 2) no data for OECD inventories before 1988, 3) OECD petroleum product consumption only captures 60% of world petroleum product consumption on average over 1992–2015. For the detailed information, we refer the interested reader to BH19 (p. 1888).

¹⁴Since the elements in *epsilon* are contemporaneous corrected, the additional conditions have been added to the system of the equation (3). Please see the details in BH 2019.

¹⁵As Herrera and Rangaraju (2020) points out that the price of oil in the U.S. was regulated by the Texas Railroad Commission until the early 1970s and it may not reflect the fluctuation of the world price.

Each equation yields the effect of the different structural shocks on the U.S. output and inflation, respectively. The results are presented in the next section.

5. Estimated results

5.1. Impulse response of oil market variables

Figure 1 reports the responses of world oil production, real global economic activity, and real price of oil to oil market structural shocks on the K09 specification. The graphs depict one and two standard error bands for the results. We explore the variables' responses to the structural shocks in two different time frames; Figures 1(a and b) show the responses of variables in the VAR with data from 1976 to 2008 and the entire sample period data set, from 1976 to 2017, respectively. Through this analysis, we examine whether there is a difference in the response of variables to the oil market structural shocks due to the structural changes after the 2008–2009 recession.

In line with the findings from the literature (e.g., K09 and Kim & Vera, 2019), the response of oil production stays significantly negative to oil supply shocks. World oil production increases significantly with a delay of 7–8 months to the aggregate demand shock in the estimation with pre-2008 data, while it has a relatively small response to the same shock in the extended full sample period. The world oil production responses to the oil-market specific demand shocks remain minimal and insignificant in both sample periods.

Consistent with Kilian (2009) findings, the impulse response function graphs show that the real oil price responds positively and significantly to aggregate demand shocks and oil-market specific demand. The response of the oil price to oil supply shocks is still positive but relatively smaller. There is no significant difference between Figures 1(a and b) for oil-market specific demand shocks. The results are quite similar to the results in Kilian's original paper (K09).

Figure 2 reports the responses of the variables to the three structural shocks: flow supply, flow demand, and speculative demand shocks along with the corresponding point-wise 68% posterior error bands. Following KM14, we obtained the results from the reduced-form posterior distribution. A negative unanticipated flow supply shock (a.k. a. oil supply shocks) causes an immediate reduction in oil production and oil inventories. Oil inventories persistently decrease even when oil production increases right after the immediate drop due to the oil supply disruption. The real oil price rises immediately in response to flow supply shocks and gradually returns to its original levels after 10 to 15 months.

A flow demand shock (a.k.a. aggregate demand shocks) causes a gradual increase in oil production, lasting about 15 months in the shorter sample period from 1976 to 2008. The impact of a flow demand shock to oil production is relatively less in the full sample period from 1976 to 2017. A flow of demand shock immediately raises the real price of oil, and the impact of the shock persists immediately and dramatically. The impact of the shock is persistent over the horizon in both sample periods. The responses of oil inventories to a flow of demand shock are negative.



(a) 1976:2 - 2008:12



(b) 1976:2- 2017:12

Figure 1. Responses of oil market variables: K09's specification. (point estimates with one and two standard error bands)

G. KIM AND D. VERA (پ



(a) 1976:2 - 2008:12



(b) 1976:2- 2017:12

Figure 2. Responses for oil market variables: KM14's specification.

866

The positive speculative demand shock (a.k.a. oil-market specific demand shocks) causes the immediate and persistent increase in oil inventories. Oil production falls after the same shock; in contrast, the real price of oil increases. The impact of a speculative demand shock on the real price of oil is significantly greater in the shorter sample period from 1976 to 2008. The response of oil production to the positive speculative demand shocks becomes relatively smaller in the full sample period from 1976 to 2017.

Figure 3 reports the responses of the variables to the four structural shocks: oil supply, economic activity, consumption demand, and inventory demand shocks on the BH19 specification.

As we observed in previous alternative specifications (e.g., K09 and KM14), the response of oil production to the oil supply shocks is significantly negative. The response of oil production is rather dramatic and immediately positive to the economic activity shocks (a.k.a. aggregate demand shocks) in the BH19 specification. Oil production responds positively after 7–8 months of delay to the same shock in the K09 specification.

In response to the negative oil supply shock, the real oil price increases immediately and remains significantly positive. In the BH19 specification, the real oil price responds positively to all four structural shocks. Moreover, the impulse response graph shows that the response of the real price of oil to the economic activity shocks is much greater than that to other shocks. The results are consistent with the original findings in BH19. Oil stocks respond insignificantly negatively to the oil supply shocks and to the economic activity shocks. In contrast, oil stocks respond very positively to the inventory demand shocks (a.k.a. oil-market specific demand shocks). Similar results from the impulse response graphs over the two sample periods suggest no structural change.

Overall, the responses of the real price of oil are mostly positive to all three structural shocks in all alternative specifications.¹⁶ Furthermore, with our findings in Figures 1–3, we conclude that the response of the real oil price to the aggregate demand shock is much greater than the responses to the other shocks in all three specifications. Also, with the exception of the responses of variables to the speculative demand shock in KM14, there are consistent results of the impulse responses of oil market variables in the two different sample periods across the alternative specifications.

5.2. Impulse response graphs of the U.S. local economy

In this section, we examine how the structural shocks from the three different alternative specifications in the previous section affect the U.S. macroeconomy, especially real GDP growth and CPI inflation. To examine the effect of the structural oil shocks on the U.S. macroeconomy, we follow Kilian (2009)'s methodology. K09 estimates the effect of the three structural oil shocks on CPI inflation and real GDP in the U.S. economy. The methodology is summarized in section 3.4. As in the previous section, we also provide the results for two different sample periods (1976–2008, 1976–2017) to examine any possible structural change after 2009 in the U.S.

¹⁶Although there is additional structural shock, consumption demand shock, in BH19, our main focus is the three structural shocks, such as oil supply, aggregate demand, and speculative oil-market specific demand shocks, which have been considered the major sources of the fluctuation of the price of oil in the literature.



(a) 1976:2 - 2008:12



(b) 1976:2- 2017:12

Figure 3. Responses for oil market variables: BH19's specification.



Figure 4. Responses of U.S. Real GDP.

Figure 4 summarizes the responses of the real GDP in the U.S. to each structural shock estimate based on the model specifications in K09, KM14, and BH19 that we describe in section 4.¹⁷

¹⁷To make the different results comparable, we name the shocks as oil supply shocks, aggregate demand shocks, and oil market specific demand shocks, following Kilian (2009). Refer to Kilian (2009), Kilian and Murphy (2014), and Baumeister and Hamilton (2019) to find how they designate shocks.

One of the important findings is that the response of the real GDP remains negative to the oil supply shocks regardless of the model specifications for both sample periods. In K09 and KM14, the negative responses of the real GDP are statistically significant within the one-standard error bands at most horizons in both sample periods. In BH19 specification, the response of the real GDP to oil supply shocks is somewhat muted in the first year, followed by a gradual negative response in the short sample (1978–2008), while the response of the real GDP in the full sample (1978–2016) follows a similar pattern albeit somewhat diminished. In sum, under the different specifications, oil supply shocks have a negative effect on the U.S. real GDP, albeit the magnitude of the drop differs.

The results from K09 and KM14 methodologies in Figure 4 indicate that the unexpected positive aggregate demand shocks lead to an economic downturn one year after the shocks. Similar results can be found in K09. According to K09, positive aggregate demand shocks can provide a positive impact on the U.S. economy in the short run. However, this favorable impact on the U.S. economy will quickly die out due to higher commodity prices. Meanwhile, the responses of the real GDP to the same shock in BH19 are persistently positive. The response of real GDP in BH19 is significantly positive at all horizons in both sample periods. We will address in detail the different responses of the real GDP to the aggregate demand shocks across the specifications (especially between K09, KM14 vs. BH19) in section 6.

The real GDP responses to oil-market specific demand shocks slightly vary across the alternative models. Unanticipated oil-market specific demand shocks lower the real GDP gradually in K09. In K09, the response of the real GDP to the oil-market specific demand shocks is not significantly responsive until ten quarters after the shocks. In contrast, the real GDP increases steadily after the shocks in KM14 and BH19 identifications with the full sample period (1978–2017).¹⁸ It is important to note that oil-market specific demand shocks in K09 are in fact residuals of the other two structural shocks so that may be caused by other factors. Therefore, the results in K09 could misinform the response of the real GDP to the oil-market specific shocks. To resolve this issue, KM14 includes above-ground crude oil inventories in the SVAR to capture the oil-market specific demand shocks. The real GDP does not respond significantly to oil consumption shocks in BH19 specification in either of the sample periods.

Figure 5 shows our estimates of the responses of the CPI to structural oil price shocks in the U.S., following the model specification in K09, KM14, and BH19.

While we find a consensus result that the negative response of U.S. real GDP to the oil supply shocks across the three alternative model specifications, we see slightly different results of the response of U.S. CPI for the alternative models. For instance, at least to some degree, all three structural shocks cause increased prices in both sample periods in K09. Concurrently, in KM14 specification, while the response of the CPI to the oil supply shocks is dull and statistically insignificant at all horizons in the sample period of 1978–2008, the response of CPI to the same shocks becomes significantly negative within a year and a half after the shock in the extended sample period, 1978–2017. Similar results of the response of CPI to the oil supply shocks can be found in BH19. CPI does not respond

¹⁸The third shock in K09 is the residuals of the other shocks and there is no inventory demand shock in K09.



Figure 5. Responses of U.S. CPI.

much to the oil supply shocks in both sample periods in BH19 as well. Overall, our findings do not indicate an inflationary impact on the U.S. macroeconomy due to the oil supply shocks.

Our results on the different responses of U.S. CPI to the oil supply shocks and the aggregate demand shocks can also be found in the literature. Aastveit (2014) developed a factor augmented VAR (FAVAR) model to explore the link between the oil market, the US macroeconomy, and monetary policy. The author found that, depending on the source of the shocks, U.S. macroeconomic variables respond differently to oil shocks. He concludes that there is a relatively weak negative response of U.S. real GDP after oil supply shocks and the U.S. price; similarly, federal funds rate do not respond strongly to oil supply shocks. With the insignificant response of the federal funds rate to the oil supply shocks in his finding, he concludes that not much monetary policy action has been involved with the oil supply shocks. On the other hand, the author finds that the response of the U.S. price level is significantly positive to the aggregate demand shocks, and the response of the federal funds rate to the oil supply shocks in his finding to the total supply shocks is also significantly positive.

Kilian (2009) also shows that the price level in the US reacts differently to the different sources of the oil shocks. He also finds an insignificant response of the U.S. price level to the oil supply shocks. In contrast, the response of the same variable is positively significant to the aggregate demand shocks.

Interestingly, according to our results, it appears that the aggregate demand shocks and the oil-market specific shocks have permanent positive effects on the U.S. inflation in both sample periods in all three alternative specifications. This suggests that the U.S. CPI appears to be most responsive (positive) to aggregate demand shocks. When comparing the two estimation periods to see the possible change in pass-through in the U.S., the response of CPI appears similar in both sample periods.

Overall, our results in Figure 5 suggest that the aggregate demand shocks and oilmarket specific shocks appear to have a positive effect on CPI, while there is little evidence of inflationary impact from the oil supply shocks. We also find that the response of the CPI to the three shocks is quite consistent in different sample periods.

6. Explaining the difference in the effects of aggregate demand shocks on output

From our impulse response results in the previous section, although there is a consensus movement of real GDP after an unexpected oil supply shocks in all three specifications, the responses of real GDP to the aggregate demand shocks in K09 and KM14 are different from the response of real GDP to the same shocks in BH19.

Oil supply shocks, under the different specifications (K09, K14, and BH19), have a negative effect on real GDP, albeit the magnitude of the drop differs. In the case of aggregate demand shocks, real GDP increases initially followed by a gradual decrease as a response to the positive aggregate demand shocks in K09 and KM14, while the response of the real GDP in BH19 is persistently and significantly positive. As shown in our results in Figure 4, the response of GDP tends to be more positive to the aggregate demand shocks from the world industrial production index in BH19 than Kilian's global



Figure 6. Robustness test with the world industrial production index in K09 and K14 (1978–2017).

economic activity index in K09 and KM14. As we mentioned earlier, the index of global real economic activity developed and modified by Kilian (2019) is used in K09 and KM14, while the world industrial production index, used in BH19 as a measure of global economic activity, includes industrial production for OECD and six major non-OECD members.¹⁹

To explain the difference in the effects of aggregate demand shocks on output in the different model specifications, we conduct a robustness check replacing the index of monthly global real economic activity by Kilian (2019) with the world industrial

¹⁹Readers can find the details from Hamilton (2019), Kilian (2019), and Kilian and Zhou (2018).



Figure 7. Robustness test with the global real economic activity index by Kilian (2019) in BH19 specification for the period 1978–2017.

production index from Baumeister and Hamilton (2019) as the measure of the global economic activity. To be consistent with Kilian's global real economic activity index, we detrend the world industrial production series (Herrera & Rangaraju, 2020), Kim & Vera, 2019).

Figure 6 shows the responses of U.S. real GDP and CPI to the structural components of oil shocks when we used the world industrial production index from Baumeister and Hamilton (2019) in K09 and KM14 specifications. The responses of U.S. real GDP and CPI in Figure 6 shows the same pattern as in Figures 4 and 5, with a variation in the response of GDP to the aggregate demand shocks. In Figure 6, the response of real GDP is significantly positive right after the aggregate demand shocks occur. This positive response of real GDP stays for the first six quarters, while it is rather less responsive to the same shocks in the original results with Kilian's global index in K09 and KM14. This pattern suggests that the world industrial production index might lead to a more positive response of the real GDP than the Kilian's index of global real economic activity.²⁰ The debate on the global economic activity proxy has been an ongoing battle in the literature.²¹ The responses of CPI to the three oil shocks with the alternative world

²⁰This is consistent with the findings from Kim and Vera (2019).

²¹The details of the debate can be found from Kilian (2019), Kilian and Zhou (2018), Hamilton (2019), Baumeister and Hamilton (2020).

OECD activity index are mostly consistent with the original results in Figure 5 at least for the first four months. For instance, the positive responses of CPI to the three oil shocks in K09 also are shown in the robustness test with the world industrial production index, at least for the earlier horizons in the graphs.

Figure 7 shows the responses of U.S. real GDP and CPI to the four components of oil shocks when we used the global real economic activity index by Kilian (2019) in BH19 specification. Consistent with the previous findings, the responses of U.S. real GDP and CPI to the components of oil shocks in Figure 7 show the same pattern as in Figures 4 and 5, with a variation in the response of GDP to the aggregate demand shocks. While the response of real GDP is significantly positive right after the aggregate demand shocks occur in Figure 4, the size of this positive response of real GDP is rather smaller in Figure 7. Overall, our robustness test results suggest that 1) the use of the world industrial production index to capture aggregate demand shocks might lead to a more positive response of the real GDP than the Kilian's index of global real economic activity and 2) our main findings in Figures 4 and 5 are robust.

7. Conclusion

We examine how structural oil price shocks from alternative identification specifications affect the U.S. economy, in particular, U.S. real GDP and price level. Rather than looking at oil supply shocks only, following the existing literature, we estimate alternative shocks from the oil market (e.g., aggregate demand shock, oil-specific demand shock, and the oil consumption shock) and compare their effects on the U.S. economy.²² First, by conducting the impulse response analysis for the oil market variables under three different specifications, we find that the responses of the real price of oil are positive to all three structural shocks in all alternative specifications. Furthermore, we conclude that the responses to the other shocks in all three specifications.

Second, we are able to provide a comparative analysis of the effects of the different shocks on the economy over time and evaluate the response of both U.S. real GDP and inflation to the shocks. One of the major findings of the paper is that the oil supply shocks tend to have a negative effect on U.S. real GDP regardless of the model specification as consistent with the literature. However, the prediction of the effect of aggregate demand shocks on U.S. real GDP in the first two specifications, although initially positive, has a negative effect on longer horizons, while aggregate demand shocks from the third model have a positive effect on real GDP. In any case, aggregate demand shocks appear to be substantial under all specifications. Our findings hold in a shorter sample (through 2008) and in a larger sample (through 2017). Our results also suggest that oil-market specific demand shocks (a.k.a. speculative demand shocks) can also affect real GDP to some degree, but we could not find any consensus on the responses of U.S. real GDP to the oil-specific demand shocks across the alternative methodologies.

²²The oil consumption shock is also extracted along with other major sources of oil shocks for Baumeister and Hamilton (2019) methodology.

The effect of the different oil shocks on the price level varies. For instance, we have mixed responses of the price level to oil supply shocks under different specifications, while, at least to some degree, oil supply shocks cause an increase in the price level in the first specification; the price level does not respond much to the oil supply shocks in both sample periods in the other two. This result also holds for both sample periods. In the case of the price level, the effect of oil supply shocks is rather unsubstantial compared to the effect of the aggregate demand shocks. Overall, our results suggest that the aggregate demand shocks and oil-market specific shocks appear to have a positive effect on the price level, while there is little evidence of inflationary impact from the oil supply shocks. This finding is consistent with the current literature.²³ Exploring the possible explanations of the transmission of oil shocks to prices could be a potential new path of research. Since the response of output and the price level could vary depending on the source of the shock, identifying the source of the price of oil fluctuation might be one of the critical steps to evaluate the impact of the price of oil on economic activity. In sum, our findings suggest that 1) oil supply shocks can cause an economic downturn with little effect on inflation, 2) aggregate demand shocks can lead to higher prices and 3) oil-market specific demand shocks can lead to a somewhat positive impact on output with inflation.

Following our findings, it is important for policymakers to identify the source of the oil price fluctuation. For instance, when experiencing oil price volatility due to oil supply shocks which most likely lead to drop in GDP, it may be important to intervene to support output. Note that in this case the moderate response of the price level to oil supply shocks provides latitude for policy intervention. On the other hand, when the source of oil price fluctuation is aggregate demand shocks, policymakers should be aware of the effect on inflation and respond accordingly. For instance, under an inflation targeting regime, it may be important to intervene to counteract the rise in inflation. As for the case where oil price fluctuations are caused by oil-market specific demand shocks, it may be reasonable to pay close attention to the magnitude of the changes in GDP and Inflation and avoid reflexive actions, since the changes should not be substantial, policy intervention may not be warranted.

Acknowledgments

The authors thank Drs Ana Maria Herrera and Sandeep Kumar Rangaraju for their valuable comments and Dr Lutz Kilian for clarifying the details on how to construct the proxy of the world inventory series in Kilian and Murphy (2014).

Disclosure statement

No potential conflict of interest was reported by the author(s).

²³Kilian (2009) and Aastveit (2014)

References

- Aastveit, K. A. (2014). Oil price shocks in a data-rich environment. Energy Economics, 45, 268-279.
- Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics*, 131(4), 1593–1636.
- Baumeister, C., & Hamilton, J. D. (2019). Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks. *American Economic Review*, 109(5), 1873–1910.
- Baumeister, C., & Hamilton, J. D. (2020). Structural interpretation of vector autoregressions with incomplete identification: Setting the record straight. *Working Paper*.
- Davis, S. J., & Haltiwanger, J. (2001). Sectoral job creation and destruction responses to oil price changes. *Journal Monetary Economics*, 48(3), 465–512.
- Diebold, F. X., & Yilmaz, K. (2014). On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics*, 182(1), 119–134.
- Hamilton, J. D. (1988). A neoclassical model of unemployment and the business cycle. *Journal Political Economy*, 96(3), 593-617.
- Hamilton, J. D. (2003). What is an oil shock? Journal of Econometrics, 113(2), 363-398.
- Hamilton, J. D. (2019). Measuring global economic activity. *Journal of Applied Econometrics*, 1–11. doi:10.1002/jae.2740
- Hausman, J. A., & Newey, W. K. (1995). Nonparametric estimation of exact consumers' surplus and deadweight loss. *Econometrica*, 63(6), 1445–1476.
- Herrera, A. M., & Rangaraju, S. K. (2020). The effect of oil supply shocks on U.S. economic activity: What have we learned? *Journal of Applied Econometrics*, 35(2), 141–159.
- Ji, Q., Shahzad, S. J. H., Bouri, E., & Suleman, M. T. (2020). Dynamic structural impacts of oil shocks on exchange rates: Lessons to learn. *Economic Structures*, 9, 20.
- Kilian, L. (2008). The economic effects of energy price shocks. *Journal of Economic Literature*, 46 (4), 871–909.
- Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. *The American Economic Review*, *99*(3), 1053–1069.
- Kilian, L. (2017). The impact of the fracking boom on Arab oil producers. *Energy Journal*, 38(6), 137–160.
- Kilian, L. (2019). Measuring global real economic activity: Do recent critiques hold up to scrutiny? *Economics Letters*, *178*, 106–110.
- Kilian, L., & Murphy, D. (2012). Why agnostic sign restrictions are not enough: Understanding the dynamics of oil market VAR models. *Journal of the European Economic Association*, 10(5), 1166–1188.
- Kilian, L., & Murphy, D. (2014). The role of inventories and speculative trading in the global market for crude oil. *Journal of Applied Econometrics*, 29(3), 454–478.
- Kilian, L., & Zhou, X. (2018, November). Modeling fluctuations in the global demand for commodities. *Journal of International Money and Finance*, 88, 54–78.
- Kilian, L., & Zhou, X. (2019). Oil prices, exchange rates and interest rates. *Working Paper Federal Reserve Bank of Dallas*. 1914.
- Kim, G., & Vera, D. (2019, August). Revisiting and extending Kilian's (2009) findings. *Energy Economics*, 82, 201–210.
- Ready, R. C. (2018). Oil prices and the stock market. Review of Finance, 22(1), 155-176.
- Shahzad, S. J. H., Bouri, E., Raza, N., & Roubaud, D. (2019). Asymmetric impacts of disaggregated oil price shocks on uncertainties and investor sentiment. *Review of Quantitative Finance and Accounting*, 52(3), 901–921.
- Sweeney, J. L. (1984). The response of energy demand to higher prices: What have we learned? *American Economic Review*, 74, 31–37.
- Zhou, X. (2020). Refining the workhorse oil market model. *Journal of Applied Econometrics*, 35(1), 130–140.