# The Impacts of Structural Oil Shocks on Macroeconomic Uncertainty: Evidence from a Large Panel of 45 Countries[#]

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## Highlights

- This paper examines the impacts of oil shocks on uncertainties in a large group of 45 economies.
- A local projection method is used and linear and nonlinear impulse responses are identified.
- The impacts of oil shocks on macroeconomic uncertainty are regime-dependent.
- Macroeconomic uncertainty reacts positively to oil supply shocks during high-volatility periods.
- The impacts of oil shocks on uncertainties experience dramatic changes in the post-GFC period.

## Abstract

Using local projection methods, this paper employs monthly panel data from 1989 to 2017 to examine both linear and nonlinear impulse responses of macroeconomic uncertainty to structural shocks to global oil production, aggregate demand, oil-market-specific demand and speculative demand in a large group of 45 economies. We find that both oil supply and demand shocks are important drivers of uncertainty. There is strong evidence that the impacts of oil price shocks on macroeconomic uncertainty are regime-dependent and contingent on the states of investor sentiments and perceived volatility in financial markets. The responses of economic

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uncertainty to oil shocks, especially demand-side shocks, appear to experience a dramatic change in the post-Global Financial Crisis period.

**Keywords:** Oil shocks, uncertainty, local projections, regime-dependent impulse responses

**JEL Codes:** C22, Q02

## 1. Introduction

The macroeconomic effects of oil price shocks have been widely studied in the literature since the seminal work of Hamilton (1983). It is well established that oil shocks are closely associated with a number of macroeconomic and financial variables, including employment, aggregate output, inflation, stock returns and exchange rates (see, e.g., Antonakakis et al., 2017; Chisadza et al., 2016; Gkillas et al., 2020; Hollander et al., 2019; Kilian, 2009; Kang et al., 2015). In a recent paper, Hailemariam et al. (2019) point out that existing papers have largely focused on the negative effects of oil price shocks on macroeconomic performance as evidenced by business cycles. It may be of great interest for policymakers to investigate how macroeconomic uncertainty serves as a channel through which oil market shocks spill over to the economy and to better understand the information transmission mechanism between oil shocks and economic uncertainty. Hailemariam et al. (2019) suggest that changes in oil prices can be an important driver of macroeconomic uncertainty. This is an important question, since the role of uncertainty on macroeconomic variables has attracted significant attention among financial academics, practitioners and policymakers, especially in the wake of the Global Financial Crisis (GFC). Following Bloom's (2009) influential paper, there has been a rising body of research documenting significant effects of uncertainty on economic and financial activity (see, e.g., Antonakakis et al., 2017; Bouri and Gupta, 2019; Bloom, 2014; Chuliá et al., 2017; Gupta et al., 2014, 2016). Naturally, what drives economic uncertainty is a question that is of relevance to policy authorities to devise monetary and fiscal policies to prevent recessions. At the same time, uncertainty also affects investment decisions, and hence, is a pertinent factor in determining optimal portfolio allocations by investors.

Theoretically, there are multiple channels that oil shocks affect economic uncertainty. For example, the unexpected oil price changes can exert significant impacts on the volatility of macroeconomic and financial variables (Park and Ratti, 2008). Oil price changes influence relative prices and affect exceptions of inflation and the real interest rate. The unanticipated changes in oil prices may increase fluctuations of the firm's expected cash flows, which lead to high uncertainty about future stock returns and economic performance. The consumption and investment decisions of economic agents are often influenced by oil shocks associated with uncertainty about future returns and growth perspectives, which can subsequently impact on economic uncertainty and activity (Aye et al., 2014).

Given these theoretical linkages, there has been growing research interest in the energy economics literature about the impacts of oil market shocks on uncertainty. Kang and Ratti (2013a, 2013b, 2015) and Antonakakis et al. (2014) provide empirical evidence that oil market demand shocks have long-term impacts on uncertainty, while oil supply shocks play a small role in affecting macroeconomic uncertainty. More recently, Kang et al. (2017) and Su et al. (2018) present new evidence that supply-side shocks can affect uncertainty. Focusing on the US economy, Degiannakis et al. (2018) document heterogeneous responses of economic uncertainty to oil price shocks during different time periods. In addition, Hailemariam et al. (2019) examine the relationship between oil prices and uncertainty in G7 countries and find that oil price shocks show remarkably different patterns of impact on uncertainty before and after the GFC.

Motivated by recent developments in the field, this paper investigates the effects of structural oil shocks on macroeconomic uncertainty using a large panel dataset of 45 economies. Our study is unique in that we analyse the effect of structural oil shocks on macroeconomic uncertainty for a large number of countries. Additionally, we disentangle the sources of oil price shocks and distinguish between post- and pre-GFC periods, high and low volatility regimes and net oil-importing and net oil-exporting countries in our nonlinear and regime-switching models. We consider the nonlinearity and threshold effects of oil shocks on uncertainty and examine whether these effects are regime-dependent and contingent on structural changes. It is possible that there are substantial differences in the response patterns of uncertainty to oil shocks across different time periods and volatility regimes. The distinction between oil importers and exporters is also considered in this study, given empirical evidence that oil price shocks affect the economies of oil-exporting countries differently than oil-exporting countries.[1]

To the best of our knowledge, existing studies only investigate the effects of certain types of oil shocks on uncertainty for a single economy or a small group of countries, and most previous studies compute impulse response functions (IRFs) using a traditional method under the standard structural vector autoregression (SVAR) framework. To date, no comprehensive study has examined the structural effects of oil shocks on economic uncertainty for a large panel of economies using IRFs with local projections (LP IRFs). The conventional vector autoregression (VAR) approach is often criticised for imposing implausible restrictions on the structure of the system and making strong assumptions about the underlying data-generating

[1] Existing literature provides evidence that oil price shocks affect, for example, countries' economic growth, wealth, terms of trade, economic policies, stock returns and exchange rates in different ways for oil-importing and oil-exporting countries (e.g. Antonakakis et al., 2014, 2017; Basher et al., 2016; Berument et al., 2010; Cunado and De Gracia, 2005; Wang et al., 2013).

process. As highlighted by Jaroda (2005), LPs are more robust against model misspecification and allow for weaker assumptions about the dynamics of the data-generating process. Thus, they have gained increasing popularity in empirical finance as an alternative to the VAR method for estimation of IRFs (Plagborg-Møller and Wolf, 2019). In this study, we calculate linear LP IRFs using the method proposed by Jaroda (2005) and nonlinear LP IRFs following Ahmed and Cassou (2016).

We also decompose oil shocks based on their origin—oil supply (production), economic activity (aggregate demand), oil inventory (speculative demand) and oil-market-specific (consumption demand) shocks—similar to Baumeister and Hamilton (2018). From a Bayesian perspective, Baumeister and Hamilton (2018) revisit the role of oil market shocks by relaxing some implausible identification restrictions in traditional approaches to SVARs. The study finds that short-term oil supply elasticity is considerably higher than suggested by previous studies (e.g. Kilian and Murphy, 2012, 2014). Supply shocks are important for accounting for historical oil price movements, and they can reduce economic activity after a significant lag. Baumeister and Hamilton (2018) also suggest that there is considerable measurement error when dealing with oil inventory. When measurement error is considered, oil inventory demand shocks appear to be less important than indicated by early research (e.g. Juvenal and Petrella, 2015). As a result, it is important to take oil shocks' origins into consideration when examining their impacts on economic uncertainty.

Existing studies about oil prices and uncertainty mainly use news-based uncertainty measures, such as the economic policy uncertainty (EPU) index (e.g. Antonakakis et al., 2014; Kang and Ratti, 2013a, 2013b; Kang et al., 2017; Hailemariam et al., 2019). However, data regarding EPU are available for only a relatively small group of countries. In addition, as suggested by

Ozturk and Sheng (2018), this type of uncertainty measure sets a high bar for news media coverage, meaning that uncertainty may not be sufficiently captured if reporters or editors fail or neglect to report on relevant uncertainty events. In this paper, we use the total economic uncertainty measure proposed by Ozturk and Sheng (2018) for a large group of 45 economies. This survey-based uncertainty measure provides a comprehensive measure of macroeconomic uncertainty that includes a rich information set. The new measure captures perceived uncertainty based on forecasts of market participants and reflects disagreement amongst professional forecasters in surveys.

The main findings in the paper are as follows. First, our results show that the impacts of oil shocks on macroeconomic uncertainty are regime-dependent and contingent on the states of investor sentiments and perceived volatility in financial markets. Second, we find that macroeconomic uncertainty reacts positively to oil supply shocks during high-volatility periods. Last, the impacts of oil shocks on uncertainties experience dramatic changes in the post-GFC period. Note that, our results have important implications for policymakers and investors in financial markets, given existing literature shows evidence that macroeconomic uncertainty itself leads the macroeconomy, so the role of oil shocks, and which oil shocks can predict uncertainties and the macroeconomy is clearly very important information for the policymakers and investors.

The remainder of this paper is organised as follows. Section 2 describes the data and methodology. Section 3 provides results and discussion. Section 4 concludes with summary remarks and policy implications.

## 2. Data and Methodology

The dataset used in this study consists of the macroeconomic uncertainty measures for Ozturk and Sheng (2018) for 45 economies, the volatility index (VIX) and oil market data at the monthly frequency. The sample period covers October 1989 to October 2017. The VIX index, which available from the Chicago Board Options Exchange, is commonly known as the fear index and is widely used in the literature as a proxy for investor sentiment and perceived volatility in financial markets (e.g. Bouri et al., 2018; Zhang et al., 2017). The country-specific measure of economic uncertainty is computed based on forecasts of eight macroeconomic variables related to market participants in their home countries: the annual growth rates of GDP, investment, consumption, industrial (manufacturing) production, short- and long-term interest rates and unemployment and inflation rates. This survey-based uncertainty measure reflects professional forecasters' perceptions of future economic developments and captures both common and idiosyncratic components of uncertainty in the whole economy. To measure oil market shocks, we employ the method proposed by Baumeister and Hamilton (2019) and disaggregate oil market shocks into four components, i.e., oil supply shocks (OSS), economic activity shocks (EAS), oil consumption demand shocks (OCDS) and oil inventory demand shocks (OIDS). These shocks are derived from the structural model of the oil market with each of them capturing distinct aspects of the demand and supply sides of the oil market. We use the quantity of global crude oil produced, the real price of oil, real economic activity and crude oil inventories to describe the global oil market in a system and identify oil market shocks. The production of world crude oil (taken from the US Energy Information Administration database) is used as a proxy for oil supply. The real price of oil is calculated by deflating the nominal spot prices of West Texas Intermediate crude oil (taken from the US Energy Information Administration database) using the US consumer price index (taken from the Federal Reserve Economic Data database). The industrial production index, which includes the Organisation for Economic Co-operation and Development (OECD) countries; Brazil, Russia, India, China, and South Africa; and Indonesia (taken from the Main Economic Indicators database of the OECD), is used as a proxy for real economic activity. An estimate of crude oil inventories (i.e. the quantity of oil that is produced but not consumed) is calculated by multiplying US crude oil stocks by the ratio of the petroleum inventory of the OECD to that of the US (taken from the EIA database).

To examine the effects of oil shocks on uncertainty, we first employ the LP method proposed by Jorda (2005) as a benchmark model. The linear model for computing LP IRFs for panel data is as follows:

$$Y_{i,t+s} = \alpha_{i,s} + Oil\ Shock_t \beta_s + \epsilon_{i,t+s},\ \text{for } s = 0,1,2, \dots h, \qquad (1)$$

where $Y_{i,t}$ represents the total uncertainty of country $i$ in period $t$, $s$ is the length of forecast horizons, $h$ is the maximum length of forecast horizons,[2] $\alpha_{i,s}$ captures the country fixed effect and $\beta_s$ measures responses of uncertainty at time $t + s$ to an identified oil shock at time $t$. The LP IRFs can be constructed as a sequence of $\beta_s$ separately estimated for each horizon ($s$) using simple least squares.[3] Note that, the LP method computes impulse responses that do not require specification and estimation of the underlying multivariate dynamic system itself. The central

[2] The maximum length of forecast horizons is set to 24 in this study, which corresponds to 24-month forecast horizons.

[3] For a simple illustration, let us consider an univariate process, where we want to calculate LP IRFs of variable $y_t$ to a shock $u$ at time period $t$. $E[y_t]$, the point estimate of $y_t$ upon the impact of the shock at time $t$ is simply $y + u$, where $y$ is typically the mean. Assuming that $y_t$ follows an AR(2) process, the next period of the IRF can be then obtained by regressing $y_t$ on two lags of itself, i.e., $y_t = \alpha + \beta_1 y_{t-1} + \beta_2 y_{t-2} + u_t$. The IRF estimate for the period after the shock is then: $E[y_{t+1}] = \alpha + \beta_1(\bar{y} + \bar{u}) + \beta_2 \bar{y}$, and the confidence interval will be computed using the standard errors of the regression coefficients. At this point, the LP method deviates from the traditional method used in a VAR (as it avoids the cause of the biases due to model restrictions and misspecifications in the VAR approach by estimating the model locally to each forecast horizon). It forms $E[y_t+2]$ and subsequent periods using a sequence of separate OLS regressions. In order to obtain the IRF for $t+2$ the method needs to regress $y_t$ on $y_{t-2}$ and $y_{t-3}$, i.e., $y_t = \alpha + \beta_1 y_{t-2} + \beta_2 y_{t-3} + u_t$, and again $E[y_{t+2}] = \alpha + \beta_1(\bar{y} + \bar{u}) + \beta_2 \bar{y}$. However, the coefficients now take different values, with each period getting its own regression. Further details about LP IRFs techniques can be found in Jordà (2005) and Ahmed and Cassou (2016), but due to space considerations, they are not presented in this paper.

idea consists in estimating local projections at each period of interest rather than extrapolating into increasingly distant horizons from a given model, as it is done with a VAR. In other words, the analysis of the responses of total uncertainty to oil shocks does not rely on rigid identifying assumptions used normally in the VAR literature, say for example, the Wold-causal order and the Cholesky decomposition.

Following the work of Ahmed and Cassou (2016), the linear model specified in Eq. (1) can be extended to the threshold model. Using the simple dummy variable approach, the nonlinear threshold model for calculating LP IRFs is as follows:

$$Y_{i,t+s} = (1 - I_{t-1})\left[\alpha_{i,s}^{R_1} + Oil\ Shock_t \beta_s^{1}\right] + I_{t-1}\left[\alpha_{i,s}^{R_2} + Oil\ Shock_t \beta_s^{R_2}\right] + \epsilon_{i,t+s}, \text{ for } s = 0,1,2,\dots h, \quad (2)$$

where $I_{t-1}$ is a threshold dummy variable that indicates the status (regime) of economy $i$. The variable takes a value of 1 if the status of country $i$ is that of regime 2 (e.g. a net oil importer) or was before the GFC and 0 otherwise.

We also use the smooth transition function approach to switch the VIX into high- and low-volatility states. The dummy variable in Eq. (2) can be replaced by the values of the logistic function, $F(z_t)$, at $t - 1$. The regime-switching model used to distinguish the response of economic uncertainty to oil shocks during high-volatility periods from the response during low-volatility periods is as follows:

$$Y_{i,t+s} = \left(1 - F(z_{t-1})\right)\left[\alpha_{i,s}^{R_H} + Oil\ Shock_t \beta_s^{R_H}\right] + F(z_{t-1})\left[\alpha_{i,s}^{R_L} + Oil\ Shock_t \beta_s^{R_L}\right] + \epsilon_{i,t+s}, \text{ for } s = 0,1,2,\dots h \quad (3)$$

$$F(z_t) = \exp(-\gamma z_t)/1 + \exp(-\gamma z_t)\,, \gamma > 0, \qquad (4)$$

where $z_t$ is a switching variable (e.g. the VIX) that is normalised to have unit variance and zero mean. The smooth transition function, $F(z_t)$, varies between 0 and 1 and can be interpreted as the probability of being in a low-volatility regime when $z_t$ is the VIX. Values of $F(z_t)$ close to 0 correspond to periods of high uncertainty, i.e., $F(z_t) \approx 0$ if the VIX is in a high-volatility regime (i.e. regime $R_H$). Values close to 1 correspond to periods of low uncertainty, i.e., $F(z_t) \approx 1$ if the VIX is in a low-volatility regime (i.e. regime $R_L$).

## 3. Results and Analysis

### 3.1 Responses to structural shocks

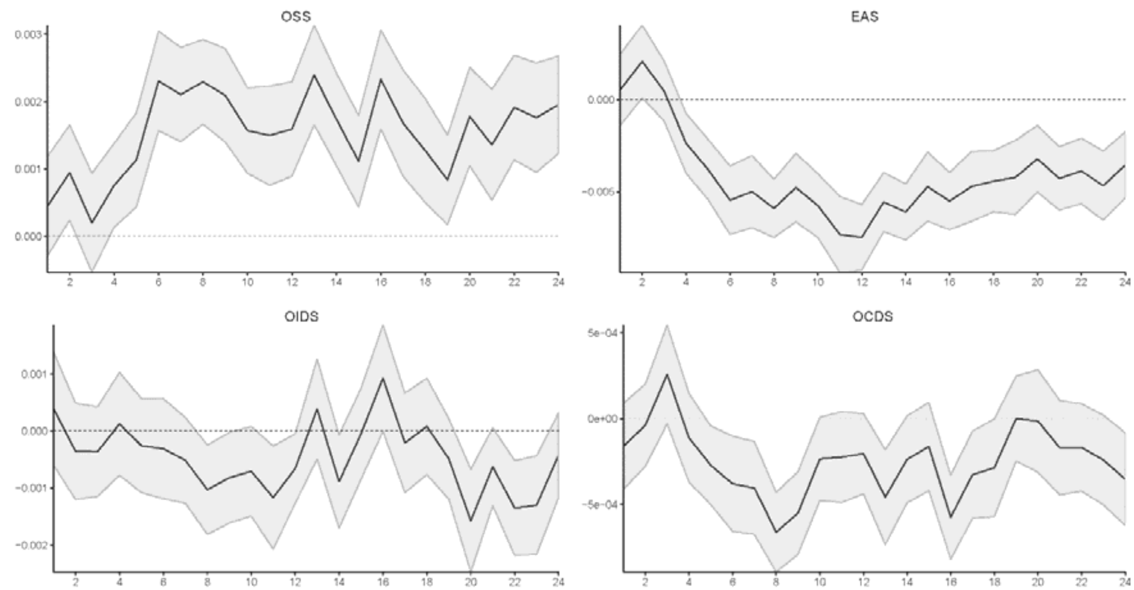
Fig. 1 reports the estimated IRF of total economic uncertainty for a 1-unit change in oil shocks over a time period of 24 months for the linear model specified in Eq. (1). The two standard error bands, indicated by grey areas, are computed based on panel-corrected standard errors (IRFs for idiosyncratic and total uncertainty are similar shown in Fig. A1).[4]

We find that an oil supply (production) shock has a persistent and positive effect on economic uncertainty. Our results show that a 1-unit increase in supply shocks raises economic uncertainty by 0.001 after 2 months and by 0.002 after 6 months. This finding aligns with the work of Baumeister and Hamilton (2018), who indicate that a positive shock to oil supply depresses oil production, increases oil prices and leads to a decline in economic activity after a significant lag. An upward oil supply shock captures bad news about the economic outlook and triggers a rise in uncertainty, which exerts negative effects on the economy. Our results are

[4] Ozturk and Sheng (2018) propose a method to decompose economic uncertainty into common and idiosyncratic components. Using this method, we compute the IRFs of both common and idiosyncratic uncertainty to oil shocks and find that IRFs for idiosyncratic and total uncertainty are similar. We report the results in the appendix.

consistent with those of Kang et al. (2017) and Su et al. (2018), who present new evidence that uncertainty rises with positive oil supply shocks.[5]

**Figure 1: Responses to structural shocks**




**Note:** The figures show impulse responses to a 1-unit increase in disaggregated oil shock up to 24 months into the future. The shaded areas represent the 95 % confidence intervals and are calculated based on panel corrected standard errors. OSS: oil supply shock; EAS: economic activity shock; OCDS: oil-specific consumption demand shock; OIDS: oil inventory demand shock.

Our results reveal that economic uncertainty substantially declines in response to positive aggregate demand shocks that are driven by fluctuations in global business cycles (i.e. higher economic activity shocks). An economic activity shock has a persistent and profound negative effect on economic uncertainty, and its largest impact is expected to occur with a delay of 12 months. Our results show that a 1-unit increase in the economic activity shock is associated with a decrease in economic uncertainty of about 0.005 after six months. The negative impact of economic activity shock on economic uncertainty can be explained by the surge in global

[5] Kang et al. (2017) find that the response of uncertainty (measured by the EPU) is positive and statistically significant to US oil supply shocks. Su et al. (2018) report a positive relationship between oil supply shocks and a news-based uncertainty measure: news implied volatility.

aggregate demand, which creates a positive outlook for the economy and tends to reduce economic uncertainty. Our finding aligns with existing literature that documents the negative responses of uncertainty to aggregate demand shocks (e.g. Antonakakis et al., 2014; Kang and Ratti, 2013a, 2013b, 2015; Kang et al., 2017).

We find that oil-market-specific demand (i.e. consumption) shocks play an important role in macroeconomic uncertainty in the medium- to long-term. Our results show that, with a delay of at least 5 months, a positive shock to consumption demand leads to statistically significant reductions in economic uncertainty. This finding contributes to the mixed results of the existing literature. For example, Kang and Ratti (2003a, 2003b, 2015) and Kang et al. (2017) report positive responses of uncertainty to oil-market-specific demand shocks. In contrast, Antonakakis et al. (2014) conclude that consumption demand shocks do not seem to trigger significant responses of uncertainty.[6] Our results may appear counterintuitive and contradictory to the work of Baumeister and Peersman (2013) and Kilian and Murphy (2012), who suggest that a positive oil-specific demand shock leads to higher oil prices, higher oil production and lower macroeconomic economic activity. However, Kilian (2009) points out that the sharp rise in oil prices since 2003 failed to cause a major recession in the US since it was driven by strong demand shocks fuelled by a booming global economy. In other words, a positive oil demand shock can be associated with higher oil prices and greater macroeconomic activity. Furthermore, as pointed out by Baumeister and Hamilton (2018), the negative response of economic activity to a positive demand shock is dependent on the primitive assumption that the feedback effect of oil production on economic activity is small. The response of economic activity to an oil-specific demand shock could be positive if oil production increases

[6] Antonakakis et al. (2014) report some evidence of negative impacts of oil-specific demand shocks on uncertainty, but they do not provide sound economic explanations for this finding.

sufficiently in response to higher oil demand and the price elasticity of the oil supply is considerably large. A positive oil demand shock can be associated with higher oil production, lower oil prices and higher economic activity in the future.[7] Our finding can be interpreted as empirical evidence implying that the feedback effect arising from the direct (delayed) response of oil production to economic activity can be strong, and thus a positive oil demand shock can lead to higher oil production, lower oil prices and higher economic activity in subsequent periods. This finding supports the work of Baumeister and Hamilton (2018), which indicates that oil-market-specific shocks can be regarded as good news, as they signal a positive economic outlook and alleviate concerns about economic uncertainty.

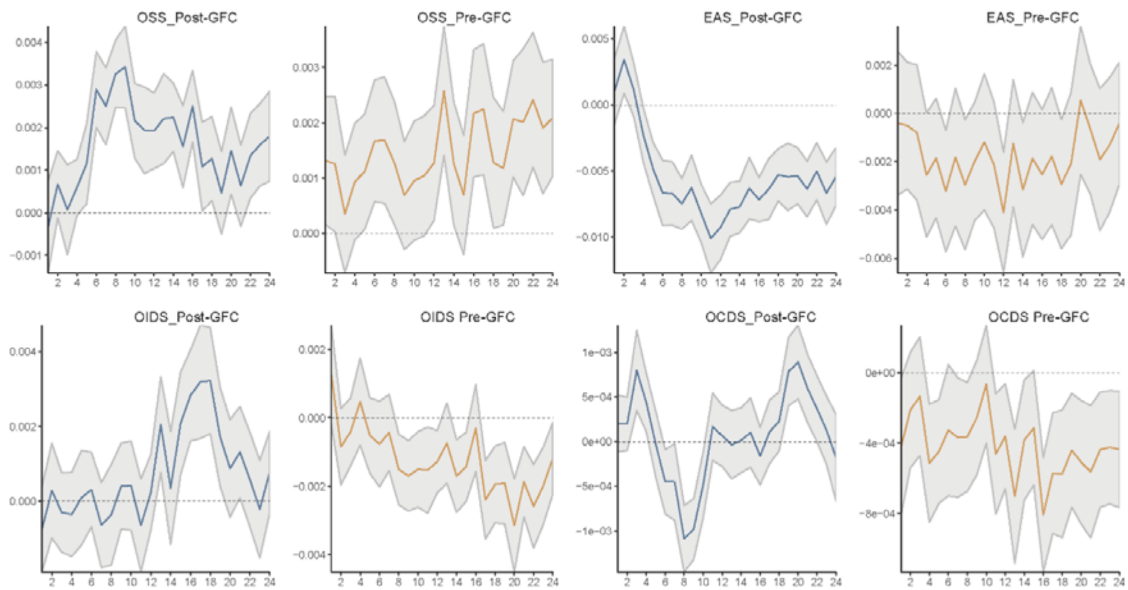
We also observe some negative responses of uncertainty to positive inventory demand shocks with a delay of at least 7 months. The impacts of oil inventory demand shocks on economic uncertainty are rather short-lived and small in size, which partially aligns with the findings of Baumeister and Hamilton (2018), who suggest that oil inventory demand shocks seem to be less important than found by early research (e.g. Juvenal and Petrella, 2015). However, Baumeister and Hamilton (2018) suggest that a positive inventory demand shock has a negative effect on economic activity due to its speculative nature, which tends to increase economic uncertainty. This seems to contradict our result that uncertainty responds negatively to a positive inventory demand shock. This peculiar effect highlights the importance of using nonlinear models in the following subsections to examine whether the results of the linear model are robust or contingent on any structural changes or regime shifts.

[7] Kilian (2009) suggests that oil producers are slow to respond to demand shocks given the cost of changes to oil production. As a result, oil supply responds to demand shocks with a delay.

### 3.2 A sensitivity test: Pre- versus post-GFC periods

To examine whether our results, which are reported in the last subsection, are sensitive to a structural change and to capture any potential difference in impacts before and after the GFC, we introduce a dummy variable that equals 1 for the pre- GFC period (i.e. before September 2009) and 0 otherwise into the threshold nonlinear model specified in Eq. (2). Figure 2 reports the IRFs of economic uncertainty after a 1-unit increase in oil shocks over a period of 24 months during the post-GFC period (first column) and pre-GFC period (second column).

**Figure 2: Responses to structural shocks (Post- vs Pre- GFC)**




**Note:** See Notes to Figure 1.

We find that compared to an instant positive response of economic uncertainty to a positive oil supply shock during the pre-GFC period, economic uncertainty is particularly unresponsive to oil supply shocks immediately after a shock during the period after the GFC. However, there is clear evidence that positive responses of uncertainty to oil supply shocks are persistent and strong during both pre- and post-GFC periods, which provides empirical evidence in support of Kang et al. (2017), Baumeister and Hamilton (2018) and Su et al. (2018).

Furthermore, our results show that the negative effects of aggregate demand shocks on uncertainty are more persistent and profound before the GFC. As shown in Figure 2, an economic activity shock has statistically significant and negative impacts on uncertainty from the 4$^{th}$ month to the 24$^{th}$ month in the pre-GFC period, and these statistically significant and negative impacts are short-lived in the post-GFC period. Our finding resonates with the work of Hailemariam et al. (2019), who suggest that the rise in oil prices during periods of pre-GFC economic booms can create a conducive environment for the economy and decrease uncertainty.

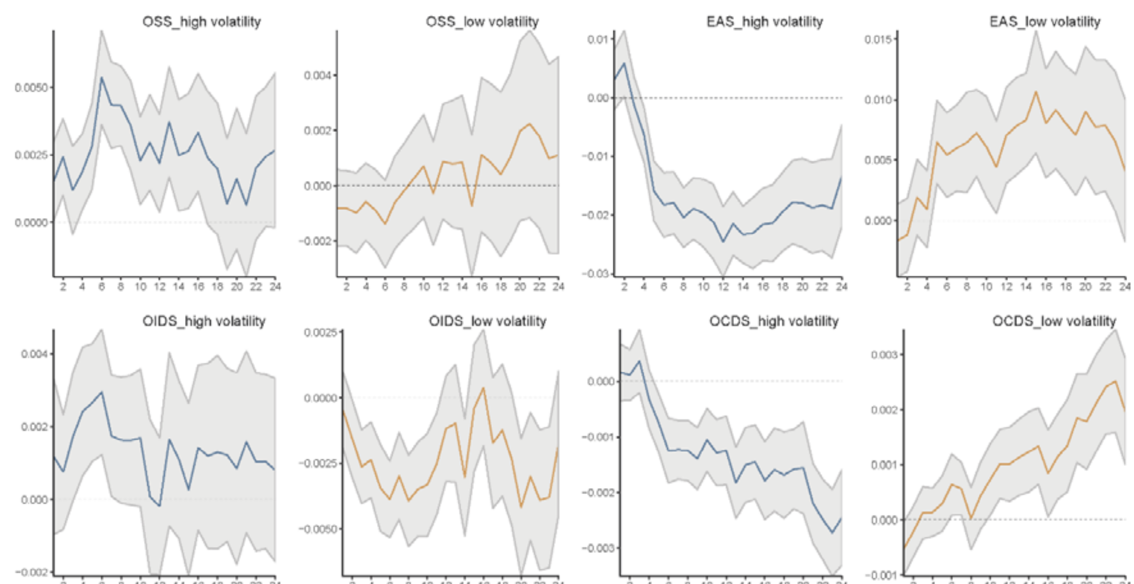
With a delay of three months, statistically significant and negative impacts of oil-market-specific demand shocks on economic uncertainty are observed in the pre-GFC period. However, there are swings in the responses of macroeconomic uncertainty to oil-market-specific demand shocks during the post-GFC period. The statistically significant effects of consumption demand shocks on economic uncertainty are negative from the 6$^{th}$ month to the 10$^{th}$ month and positive from the 2$^{nd}$ month to the 5$^{th}$ month and from the 18$^{th}$ month to the 22$^{nd}$ month. The observed positive influences of the oil-market-specific demand shock on uncertainty coincide with the findings of Kang and Ratti (2003a, 2003b, 2015) and Kang et al. (2017), according to which a positive oil-specific demand shock indicates greater concern about the shortage of future oil supplies in the market and raises uncertainty. On the other hand, the observed negative influences of the oil-specific demand shock on uncertainty may indicate the presence of a strong feedback effect that leads to higher oil production, better economic conditions and lower uncertainty.

In addition, the post-GFC period analysis indicates an increase in oil inventory demand shocks, leading to higher economic uncertainty after 12 months. This contradicts the results for the pre-

GFC period, which reveal that oil inventory demand shocks have negative impacts on uncertainty after seven months. Our finding that a positive speculative demand shock (inventory demand shock) leads to a post-GFC increase in economic uncertainty aligns with the work of Baumeister and Hamilton (2018), who suggest that a positive inventory demand shock has a negative effect on economic activity.

In summary, we find that the responses of economic uncertainty to oil shocks, especially demand-side shocks, appear to experience a dramatic change in the post-GFC period. Our findings are consistent with those of Degiannakis et al. (2018) and Hailemariam et al. (2019), who report heterogeneous responses of uncertainty to pre- and post-GFC oil shocks.

**Figure 3: Responses to structural shocks (high versus low volatility regimes)**




**Note:** See Notes to Figure 1.

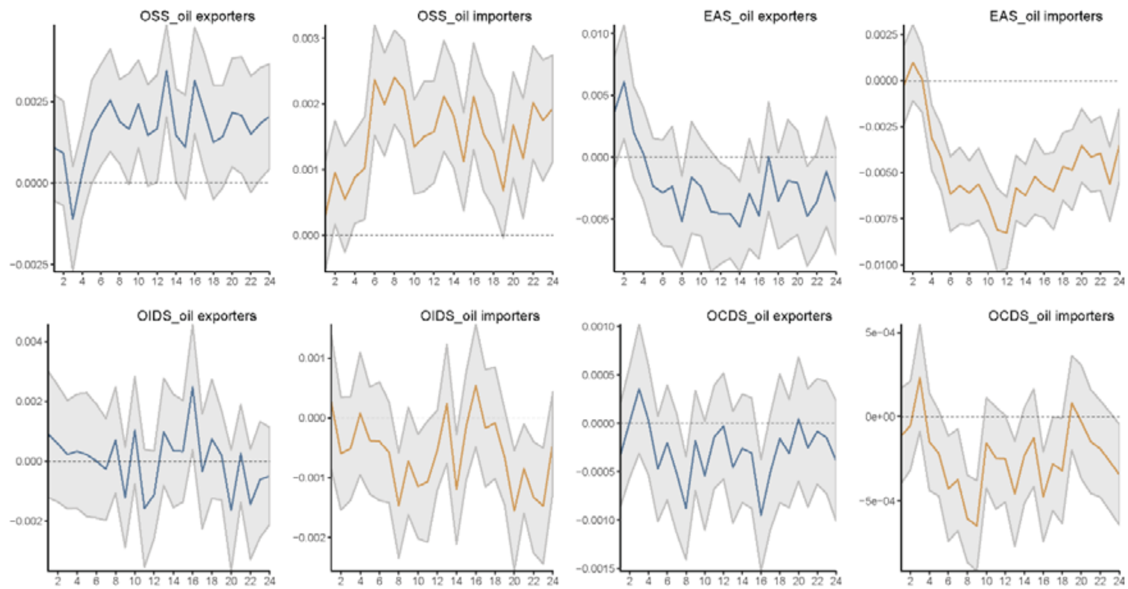
### 3.3 A sensitivity test: High- versus low-volatility regimes

In Figure 3, we present the estimated state-contingent IRFs of uncertainty for a 1-unit increase in oil shocks over 24 months in a high-volatility regime (first column) and low-volatility regime (second column). We use the regime-switching model specified in Eq. (3) and Eq. (4).

We find strong evidence that the impacts of oil supply-side shocks on macroeconomic uncertainty are regime-dependent and contingent on the states of investor sentiments and volatility in financial markets. The results show that macroeconomic uncertainty reacts positively to oil supply shocks during high-volatility periods. The positive response of uncertainty to oil supply-side shocks is consistent with our reported results in the previous subsections and with the economic explanations provided by Baumeister and Hamilton (2018) and recent empirical evidence reported by Kang et al. (2017) and Su et al. (2018). However, we find that uncertainty is not particularly responsive to oil supply shocks in low-volatility periods. Our novel results offer new insights into the macroeconomic effect of oil supply-side shocks on the economy. They consolidate the results from recent research that highlight the important role of oil supply shocks with early literature that indicates the opposite. The intuition is that oil supply shocks tend to raise uncertainty, especially during the periods when there is strong fear among investors and the perceived volatility of financial markets is high. In contrast, when the perceived volatility of financial markets is low and investors are calm, oil supply shocks are less likely to raise concerns from investors and the market about the economic outlook and thus are less likely to cause a rise in uncertainty. The results are plausible, especially in light of the evidence of the growing financialisation of oil markets (e.g. Fattouh et al., 2013) and contagion and integration between oil and financial markets (e.g. Antonakakis et al., 2017; Nazlioglu et al., 2015).

It is also evident that the impacts of demand-side shocks on economic uncertainty are dramatically different between the high- and low-volatility regimes and that these effects are asymmetrical in terms of the size and direction of the uncertainty responses to oil shocks in the two regimes. The estimated IRFs (reported in the 2nd row in Figure 4) show that economic activity shock has a persistent and profound negative impact on economic uncertainty and a unit increase in the economic activity shock is associated with a fall in economic uncertainty of about 0.02 after 12 months in turbulent periods. This is in contrast with a statistically significant positive impact during the calm periods, e.g., a 1-unit increase in the economic activity shock leads to a rise in economic uncertainty of about 0.004 after 1 year. Furthermore, we find new evidence that uncertainty responds positively to inventory demand shocks during the high-volatility periods. There is a positive and statistically significant response of uncertainty to inventory demand shocks after 16 months, although the size of the response is relatively small; a 1-unit increase in inventory demand shock leads to a 0.002 rise in uncertainty. This empirical result lends support to Baumeister and Hamilton (2018), who suggest that changes in oil inventory demand appear to have a smaller effect on oil price movements than implied by early literature. The result also aligns with existing studies (e.g. Baumeister and Hamilton, 2018; Juvenal and Petrella, 2015) that demonstrate the negative impacts of oil inventory (speculative) demand shock on economic activity. However, during high-volatility periods, we still observe a peculiar effect of negative responses of uncertainty to a positive inventory demand shock. Further work is required to explain the underlying transmission mechanism. Last, we find statistically significant and positive impacts of oil-market-specific demand shocks on uncertainty after six months in low-volatility periods, corroborating previous findings (e.g. Kang and Ratti, 2003a, 2003b, 2015; Kang et al., 2017) that positive responses of uncertainty to oil-market-specific demand shocks. Our results also show statistically significant and negative impacts of oil-market-specific demand shocks on uncertainty after five months during high-volatility periods, which indicates that oil consumption demand shocks can be interpreted as good news and reduce economic uncertainty during turbulent periods when market participants are extremely nervous about the economic outlook.

**Figure 4: Responses to structural shocks (net oil exporters vs net oil importers)**




**Note:** See Notes to Figure 1.

### 3.4 Oil-importing versus oil-exporting countries

To examine whether oil shocks have a differential effect on macroeconomic uncertainty in net oil-importing and oil-exporting countries, we introduce a dummy variable that equals 1 for net oil exporters and 0 otherwise into the model specified in Eq. (2). Figure 4 reports the IRFs of economic uncertainty for a 1-unit increase in oil shocks within 24 months for net oil-exporting countries (first column) and oil-importing countries (second column).

Figure 4 shows that the estimated IRFs derived from the nonlinear model are qualitatively similar to those from the linear model (reported in Figure 1). However, there are some differences in the strength and statistical significance of the IRFs between net oil-importing and exporting countries; we find that economic uncertainty in oil-importing countries tends to be more affected by oil price shocks than oil-exporting countries.[8] This finding aligns with the existing literature (e.g. Cunado and De Gracia, 2005), which shows that the macroeconomic response of oil importers to oil price shocks differs from that of oil-exporting countries.[9]

## 4. Conclusion

This paper analyses the responses of economic uncertainty to structural shocks to global oil supply (production), aggregate (economic activity) demand, oil-market-specific (consumption) demand and speculative (oil inventory) demand. The paper contributes to the literature by analysing both linear and nonlinear impulse responses of economic uncertainty to oil price shocks in a large panel of 45 economies using LP methods. We employ a survey-based uncertainty measure recently developed by Ozturk and Sheng (2018), which captures perceived uncertainty based on the forecasts of market participants. We disentangle the origins of oil price shocks and consider the impacts of the GFC, perceived market volatility, investor sentiments in financial markets (as captured by the VIX) and the net oil-importing/exporting

[8] The country-specific uncertainty measures are derived from unpredictable components (forecast errors) of wide data of macroeconomic variables including the growth rates of GDP, investment, consumption, industrial (manufacturing) production, the levels of short- and long-term interest rates and unemployment and inflation rates, so our results have indirectly controlled for the impact of these factors. However, based on the suggestion of an anonymous referee, we also test the robustness of our results by controlling for the principal component of a group of variables including inflation rates, foreign exchange rates, short- and long-term interest rates and industrial production of the US, developed and emerging economies, with data derived from the Database of Global Economic Indicators maintained by the Federal Reserve Bank of Dallas at: https://www.dallasfed.org/institute/dgei. The obtained results are qualitatively similar, and are available upon request from the authors.

[9] There are few studies focusing on the heterogeneous response of macroeconomic variables to oil price shocks between oil-importing and -exporting countries, and the results are inconclusive. For example, to examine the impacts of oil prices on economic activity in six Asian countries, Cunado and De Gracia (2005) use a small sample of countries that includes only one net oil exporter and five importers in Asia. They find that the relationship between oil prices and economic activity seems to be less significant for net oil exporters, although they indicate that further research is required to reach a general conclusion given the small sample size (Cunado and De Gracia, 2005). In contrast, using a sample of nine oil-importing and seven oil-exporting countries, Wang et al. (2013) find the impacts of aggregate oil demand shocks on stock markets in oil-exporting economies are stronger and more persistent than in oil-importing economies. Further, Berument et al. (2010) suggest that economic output increases with positive oil demand shocks but decreases with positive oil supply shocks for oil importers, while the output of oil exporters increases with both demand and supply shocks in 16 Middle East and North Africa countries.

position of economies. Following Ahmed and Cassou (2016), we apply the simple dummy variable approach to split the data into oil exporters and importers and pre- and post-GFC periods. We also use the smooth transition function to switch the VIX into high and low states. To the best of our knowledge, this paper is the first comprehensive study of the impacts of structural oil price shocks on macroeconomic uncertainty to use both linear and nonlinear methods for a large group of countries. In this paper, we present several novel results, reconcile previously published results and provide economic explanations for our results.

Our results show that both oil supply and demand shocks are important drivers of economic uncertainty, and there is strong evidence that the impacts of oil price shocks on macroeconomic uncertainty are regime-dependent and contingent on the states of investor sentiments and volatility in financial markets. The responses of economic uncertainty to oil shocks, especially demand-side shocks, appear to experience a dramatic change in the post-GFC period. We find that oil consumption demand shocks can be interpreted as good news and reduce economic uncertainty, especially during turbulent periods when market participants are extremely nervous about the economic outlook. We argue that the observed negative influences of the oil-specific demand shock on uncertainty may indicate the presence of a strong feedback effect arising from the direct (delayed) response of oil production to economic activity, which leads to higher oil production, better economic conditions and lower macroeconomic uncertainty. We also report new evidence that the impacts of oil inventory demand shocks on economic uncertainty are rather short-lived and small in size, and we find that economic uncertainty in oil-importing countries tends to be affected more by oil price shocks than oil-exporting countries. Further, our results show that macroeconomic uncertainty reacts positively to oil supply shocks during high-volatility periods but is not particularly responsive in low-volatility periods. These novel results provide new insights into the macroeconomic effect of oil supply-side shock, indicating that positive oil supply shocks that depress oil production and raise oil prices in subsequent periods tend to dramatically increase macroeconomic uncertainty, especially during periods when there are strong fears among investors and the perceived volatility in financial markets is high.

The findings in this paper have important implications for policymakers and investors in financial markets. In addition, our results are also important from the perspective of structural modelling, where uncertainty is often considered as purely exogenous. Our results highlight the endogeneity of uncertainty, and hence its treatment in structural vector autoregression (SVAR) models as exogenous could lead to incorrect inferences. It is also important to take both linearity and nonlinearity in models into consideration. Note that, this study uses the LP method for the in-sample analysis. For future research, it would be interesting to extend our analysis to an out-of-sample forecasting exercise, given that in-sample predictability of the macroeconomic uncertainty does not guarantee out-of-sample forecasting gains emanating from oil shocks.

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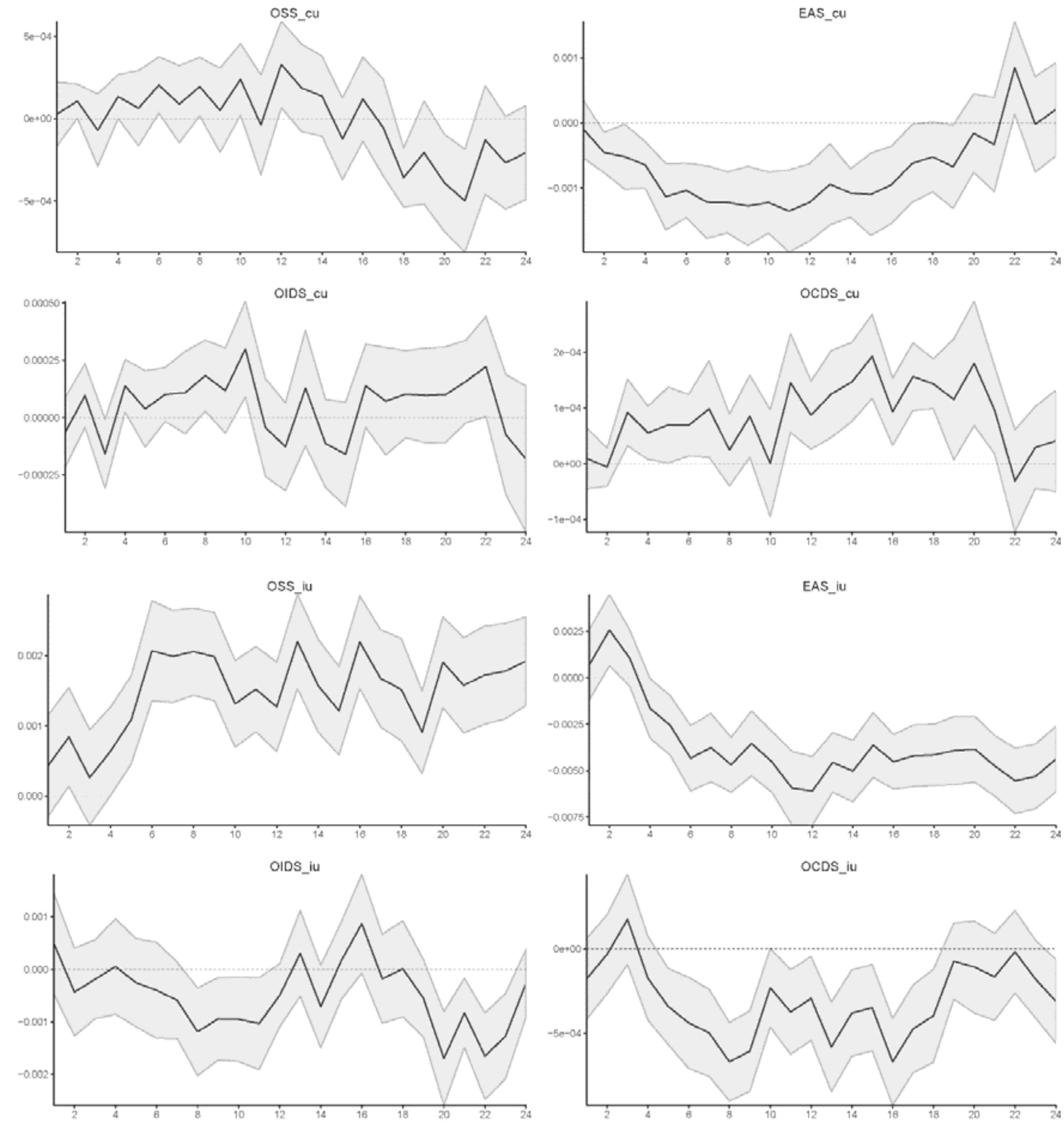
## Appendix

**Responses to structural shocks (common vs idiosyncratic uncertainty)**




**Note:** See Notes to Figure 1. Subscripts "cu" and "iu" represent common uncertainty and idiosyncratic uncertainty, respectively.