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Why Do Oil Prices and Output Move Together? State-Dependent Evidence

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ABSTRACT

This paper reexamines the relationship between oil prices and U.S. industrial production using monthly data from January 1974 to August 2025. We document three empirical patterns. First, the full-sample correlation between oil price changes and industrial production growth is positive, contrary to the conventional view. Second, this masks substantial time variation: the correlation is negative before the mid-1980s but mostly positive thereafter. Third, positive co-movement becomes substantially stronger during recessions. Using a structural vector autoregression (SVAR) that decomposes oil price movements into supply, global demand, and oil-specific demand shocks, we examine the forecast error variance decomposition (FEVD) of the real price of oil. The full-sample baseline shows oil prices are dominated by oil-specific demand shocks, with global demand shocks playing a modest role. In contrast, state-dependent results reveal that during recessions, global demand shocks account for a substantially larger share of oil price forecast error variance. Because global demand shocks move oil prices and output together, this shift explains why positive co-movement is stronger during recessions. Rolling estimation further shows that the long-run shift from negative to positive co-movement reflects changes in the transmission of oil shocks rather than a secular increase in the importance of global demand shocks.

Keywords: Oil Prices, U.S. Industrial Production, Global Demand Shocks, Structural VAR, Business Cycles
JEL Classifications: E32, Q43, C32

1. INTRODUCTION

The relationship between oil prices and real economic activity has long been a central question in energy economics. Early research, beginning with Hamilton (1983), documented a strong negative association between oil price increases and U.S. economic activity, interpreting oil price movements primarily as adverse supply shocks. Subsequent work, however, has shown that the macroeconomic effects of oil price fluctuations depend critically on the underlying sources of those price movements.

This paper revisits the relationship between oil prices and real economic activity and makes three contributions. First, we document a long-run structural shift in the oil price-output relationship using monthly data from January 1974 to August 2025: the correlation between oil price changes and U.S. industrial production growth is positive over the full sample, but negative prior to the mid-1980s and predominantly positive thereafter. Second, we demonstrate that the positive co-movement between oil prices and output is substantially stronger during recessions, and that this state dependence is explained by a pronounced shift in the composition of oil price shocks toward global demand shocks during downturns. Third, we show that this same compositional mechanism does not account for the long-run shift documented in the first contribution; the secular move from negative to positive co-movement reflects changes in the transmission of oil shocks rather than a secular increase in the share of oil price fluctuations attributable to global demand shocks.

The analysis is based on a structural vector autoregression (SVAR) of the global oil market following Kilian (2009), which decomposes oil price movements into oil supply shocks, global demand shocks, and oil-specific demand shocks. Among these shocks, only global demand shocks generate positive co-movement between oil prices and economic activity. We analyze the variance decomposition from a structural oil market VAR and examine whether the share of global demand shocks increases during recessions, as implied by the stronger positive correlation.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data. Section 4 presents empirical evidence on time variation and state dependence. Section 5 outlines the SVAR methodology. Section 6 reports the structural results, including robustness checks. Section 7 presents rolling evidence on the relationship between demand shocks and oil-output co-movement. Section 8 concludes.

2. RELATED LITERATURE

Hamilton (1983) documented a strong and statistically significant tendency for oil price increases to precede U.S. recessions, establishing the view that oil price movements are an important source of macroeconomic fluctuations. Subsequent studies reinforced this interpretation, emphasizing the recessionary effects of sharp or unexpected oil price increases (Mork, 1989; Hamilton, 1996, 2003) and attributing them to mechanisms such as higher production costs and reduced aggregate demand. Within this framework, oil price movements were treated largely as exogenous supply-side disturbances and the oil price-output relationship was implicitly viewed as stable and predominantly negative.

Over time, however, evidence accumulated that cast doubt on both the stability and the universality of this relationship. Blanchard and Galí (2009) show that the macroeconomic effects of oil price shocks weakened substantially after the 1970s, attributing this change to structural transformations such as reduced energy intensity, improved monetary policy credibility, and changes in labor market institutions. Using disaggregated data, Herrera et al. (2011) document substantial heterogeneity across industries and highlight nonlinearities in the response of industrial production to oil price changes. Related concerns about instability and nonlinear responses are raised by Kilian and Vigfusson (2011), who show that many reduced-form asymmetry results are sensitive to specification choices in the absence of explicit structural identification. More recent evidence suggests that this instability has, if anything, become more pronounced. Kwon (2024) identifies a structural change in the response of U.S. industrial production to oil market shocks around the shale oil boom and reports that oil demand shocks have come to exert a positive effect on aggregate activity. Bjørnland and Skretting (2024), estimating a time-varying parameter factor-augmented VAR on a large panel of state-level, industry, and aggregate U.S. data, similarly find that industrial production and other measures of economic activity now rise following an oil-specific shock in many states, whereas these responses were not present before the shale boom. Together, these findings suggest that average reduced-form correlations may mask important variation over time and motivate a shift toward frameworks that distinguish between different sources of oil price movements.

A major advance in this literature comes from the structural decomposition of oil price fluctuations. Kilian (2009) demonstrates that oil prices are driven by a combination of oil supply shocks, global aggregate demand shocks, and oil-specific demand shocks, each of which has distinct implications for real economic activity. This framework highlights that correlations between oil prices and output can conflate shocks with fundamentally different economic meanings. Subsequent contributions extend and refine this approach. Kilian and Park (2009) show that asset price responses to oil price movements depend critically on the underlying shock, while Kilian and Murphy (2014) enhance identification by incorporating oil inventory data to better distinguish speculative and precautionary demand forces. Related work emphasizes uncertainty about shock identification and transmission. Baumeister and Peersman (2013) show that time-varying elasticities in oil supply and demand affect the macroeconomic transmission of oil shocks, while Baumeister and Hamilton (2019) demonstrate that conclusions about the relative importance of supply and demand shocks depend sensitively on identifying assumptions and prior information. Using a global VAR covering nineteen economies, Attílio and Mollick (2025) find that industrial production declines in response to oil supply shocks but increases in response to oil demand shocks, where global demand is proxied by the Index of Global Real Economic Activity of Kilian (2009; 2019), confirming that the sign of the oil price-output relationship is shock-specific rather than fixed. These studies underscore the importance of structural interpretation, while also highlighting limits to point identification and the role of uncertainty in oil market analysis.

Building on this structural tradition, De et al. (2022) employ a factor-augmented VAR (FAVAR) with a rich information set and show that oil-specific (precautionary) demand shocks account for the largest share of oil price fluctuations, followed by global demand shocks driven by economic activity. Their forecast error variance decomposition (FEVD) results reinforce the view that demand-related forces—particularly those linked to expectations and uncertainty—are central to oil price volatility. That said, their analysis focuses on unconditional or sample-average variance decompositions and does not examine whether the composition of oil price shocks varies systematically across different phases of the business cycle.

A more recent literature examines state dependence directly, asking whether the macroeconomic consequences of oil shocks differ across phases of the business cycle. Hwang and Kim (2024) estimate a smooth transition VAR and find that oil market shocks arriving during recessions have larger and more persistent contractionary effects on industrial production than identical shocks arriving during expansions. Alsalman and Rangaraju (2026) reach a related conclusion using U.S. state-level data, showing that the responses of employment and personal income to structural oil market shocks depend on whether the economy is in a slack or non-slack state, defined by high or low unemployment, with non-oil-producing U.S. states especially sensitive to the prevailing economic state. What these studies share is that state dependence is located in the transmission of oil shocks, that is, in the magnitude and persistence of the responses a given shock elicits. The complementary possibility, that the mix of shocks generating oil price movements itself varies systematically across business-cycle states, and that this compositional shift is what drives observed changes in oil price-output co-movement, has received considerably less attention.

Taken together, the literature delivers two broad insights. First, oil price movements reflect a mixture of structurally distinct shocks whose macroeconomic implications differ markedly. Second, the relationship between oil prices and real activity is empirically unstable, varying over time and across economic environments. Existing studies, however, typically address these insights separately. Structural analyses characterize the average composition of oil price shocks without conditioning on macroeconomic states, whereas studies that document instability in the oil price-output relationship attribute that instability to changes in transmission, whether arising from declining energy intensity and improved monetary policy (Blanchard and Galí, 2009), from the shale revolution (Bjørnland and Skretting, 2024; Kwon, 2024), or from state-dependent shock propagation (Alsalman and Rangaraju, 2026; Hwang and Kim, 2024), rather than to systematic shifts in shock composition across the business cycle. As a result, the literature offers limited guidance on how these shifts relate to variation in oil price-output co-movement. Closing this gap requires separating two questions: a state-dependent variance decomposition of macroeconomic aggregates, as in Hwang and Kim (2024), answers how much of the variation in output is explained by oil shocks in each state, whereas a state-dependent variance decomposition of the real price of oil answers which shocks are moving oil prices in each state. It is the latter that governs the sign and strength of the observed co-movement.

The present analysis takes up this question, integrating these two strands by examining how the forecast error variance decomposition of oil prices differs between recession and non-recession periods, linking changes in oil price-output co-movement to systematic shifts in the composition of oil price fluctuations over the business cycle.

Two aspects of the empirical strategy distinguish this paper from the recent literature. First, rather than estimating business-cycle states within a regime-switching model, such as the smooth transition VAR of Hwang and Kim (2024), we condition on NBER recession dates, which are externally determined and therefore need not be estimated. Second, rather than augmenting the structural system with additional macroeconomic variables, we retain the standard three-variable Kilian (2009) oil market system: the aim is not to estimate the response of output to oil shocks but to trace the shifting sources of oil price movements, while keeping the shock decomposition directly comparable to the established literature.

3. DATA

This section describes the data used in the empirical analysis, including variable definitions, sources, and transformations. All variables are observed at the monthly frequency. The sample period spans January 1974 to August 2025, excluding pre-1974 data due to structural differences in oil price behavior. This period encompasses major episodes such as the oil price shocks of the 1970s, the Great Moderation, the Global Financial Crisis, the shale oil boom, and the COVID-19 pandemic.

3.1. Data Sources

The primary variables in the analysis are real oil prices and U.S. industrial production. Nominal oil prices are measured using the West Texas intermediate (WTI) crude oil spot price obtained from the Federal Reserve Bank of St. Louis FRED database (series code: WTISPLC). Real oil prices are constructed by deflating the nominal WTI price with the U.S. Consumer Price Index for All Urban Consumers (CPIAUCSL). U.S. industrial production is measured by the total index of Industrial Production published with seasonal adjustment by the Federal Reserve Board (FRED series code: INDPRO), which captures real output in the manufacturing, mining, and utilities sectors. The WTI price series has no noticeable pattern of seasonality and is used without seasonal adjustment.

Global demand conditions are represented by the index of global real economic activity (IGREA) proposed by Kilian (2009) and retrieved from FRED. This index is expressed as percent deviations from trend and incorporates the correction discussed in Kilian (2019). Kilian and Zhou (2018) emphasize the advantages of IGREA relative to measures of global GDP or global industrial production, particularly in capturing short-run fluctuations in global demand.

Recession months are defined using the NBER business cycle dates, obtained from the FRED database (series USREC). For the decomposition of oil price shocks following Kilian (2009), we use world crude oil production data, including lease condensate, measured as average daily production in million barrels per month. These data are sourced from the U.S. Energy Information Administration (EIA).

3.2. Variable Construction

To analyze the co-movement between oil prices and U.S. industrial production, the reduced-form analysis focuses on log percentage changes. Monthly industrial production growth is constructed as:

$$\Delta ip_t = 100 \times (\log(IP_t) - \log(IP_{t-1})), \tag{1}$$

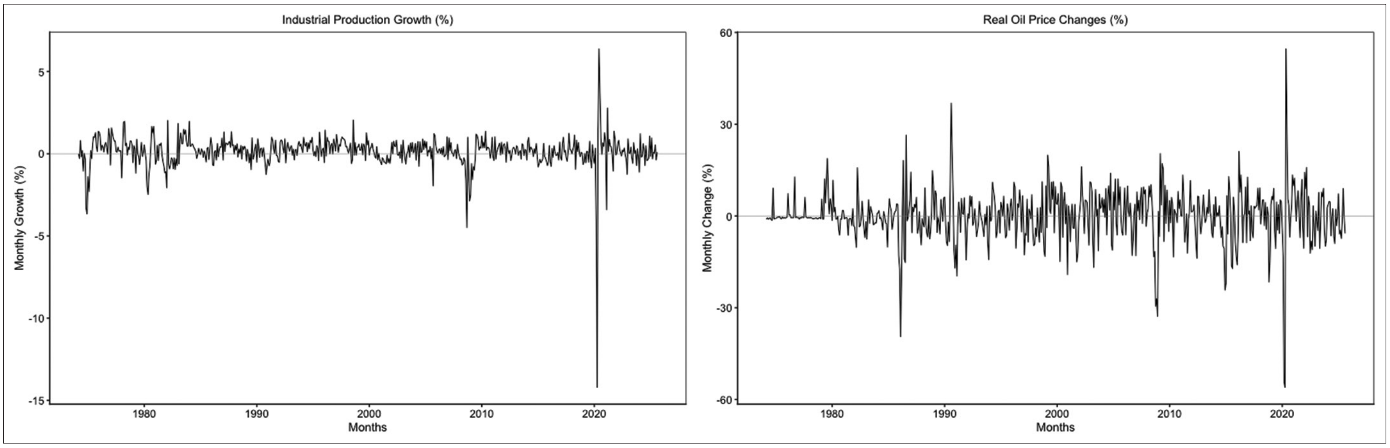
where IP_t denotes the level of the Industrial Production Index. Monthly changes in real oil prices are constructed as:

$$\Delta p_t = 100 \times (\log(WTI_t/CPI_t) - \log(WTI_{t-1}/CPI_{t-1})), \tag{2}$$

where WTI_t denotes the nominal WTI crude oil price and CPI_t denotes the consumer price index. Figure 1 plots the time series of industrial production growth and oil price changes. Both series exhibit substantial volatility. However, there is no indication of unit roots in the two time series.

While the reduced-form analysis employs oil price changes, the structural analysis uses the log level of the real oil price following Kilian (2009).

Figure 1: U.S. industrial production growth and oil price changes



Monthly log changes (×100) in the real WTI crude oil price and U.S. industrial production index, January 1974-August 2025

4. REDUCED-FORM EVIDENCE

This section presents reduced-form evidence on the relationship between real oil price changes and U.S. industrial production growth. The objective is to document key stylized facts regarding the sign, magnitude, and time variation of this relationship. These patterns help motivate the structural analysis developed in the next section.

4.1. Full-sample Correlation

We begin by examining the unconditional correlation between monthly percent changes in real oil prices and U.S. industrial production over the full sample period from January 1974 to August 2025. The correlation between monthly industrial production growth (ip_t) and lagged real oil price growth (p_{t-1}) is 0.303. A simple regression of ip_t on p_{t-1} yields an estimated slope of 0.035. Using heteroskedasticity- and autocorrelation-consistent (HAC) standard errors, the slope is statistically significant at the 5% level in a two-tailed test (P = 0.030).

We focus on the 1-month-lagged oil price change p_{t-1} rather than the contemporaneous change to mitigate within-month simultaneity between oil prices and industrial production and to give the relationship a predictive interpretation, consistent with the tradition of treating oil price movements as leading indicators of real activity (Hamilton, 1983). The 1-month lag is also the empirically relevant horizon: as shown in Table 1, correlations computed at lags of 2 through 12 months are all below 0.075 in absolute value, and the corresponding regression slopes are all below 0.009 in absolute value and statistically insignificant at the 10% level under HAC standard errors. The predictive co-movement between oil price changes and industrial production growth is therefore concentrated at the 1-month horizon.

The positive full-sample correlation indicates that oil prices and industrial production tend to move in the same direction on average. This result departs from the traditional view that increases in oil prices depress real economic activity and suggests that a more nuanced interpretation—one that accounts for the underlying sources of oil price movements—is warranted.

Table 1: Correlation and regression slope at lags 1-12

Lag *k* (months)	Correlation	Slope estimate	HAC P-value
1	0.303	0.035	0.030
2	0.040	0.005	0.541
3	−0.055	−0.006	0.549
4	−0.041	−0.005	0.596
5	0.013	0.001	0.758
6	−0.000	−0.000	0.993
7	0.015	0.002	0.630
8	−0.033	−0.004	0.292
9	−0.044	−0.005	0.333
10	0.074	0.008	0.253
11	−0.004	−0.000	0.905
12	−0.075	−0.008	0.101

The table reports the sample correlation between U.S. industrial production growth (ip_t) and real oil price change lagged by k months (p_{t-k}), together with the slope estimate from a simple regression of ip_t on p_{t-k}. The P-values are for two-tailed tests based on heteroskedasticity- and autocorrelation-consistent (HAC) standard errors. Only the 1-month lag (k=1) yields a correlation and slope that are statistically significant at conventional levels

4.2. Time Variation

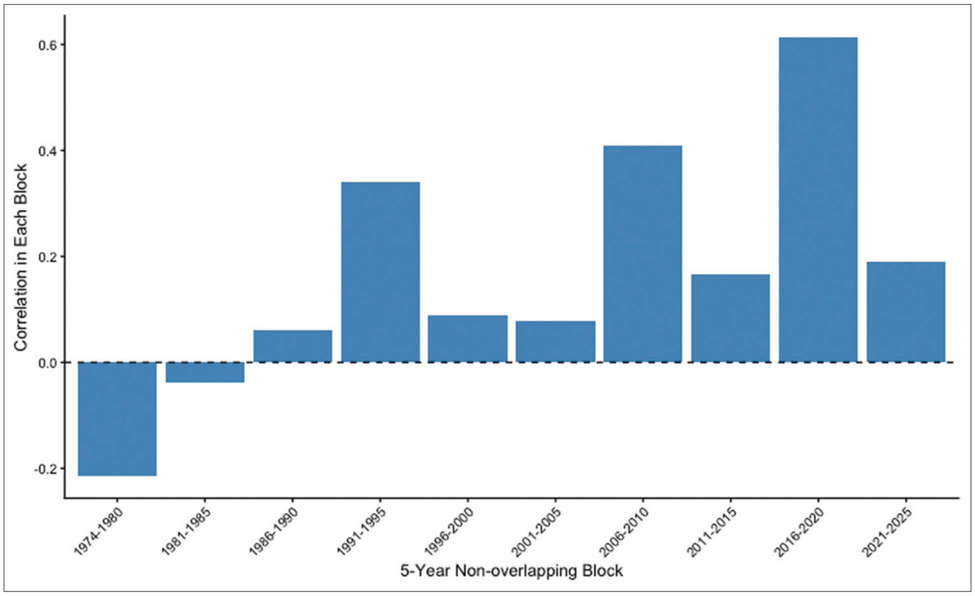
Although the full-sample correlation is positive, it does not necessarily mean that the changes in oil price and industrial production always move in the same direction. To examine the possibility of varying signs and magnitude in the correlation over time, we compute correlations using a 5-year non-overlapping window. Figure 2 plots the resulting 5-year correlations between oil price changes and industrial production growth. The correlation is negative until 1985 but turns to positive thereafter. Interestingly, when the sample size is reduced from 5 years (60 monthly observations) to 3 years (36 monthly observations), we see negative correlations appearing even after 1985, as shown in Figure 3. However, for most of the 3-year blocks after 1985 (11 out of 14) the values of the correlation are positive.

It is also notable that the largest 3-year correlations in Figure 3 coincide with the most recent recessions of 2001, 2007-2009, and 2020.

4.3. State Dependence

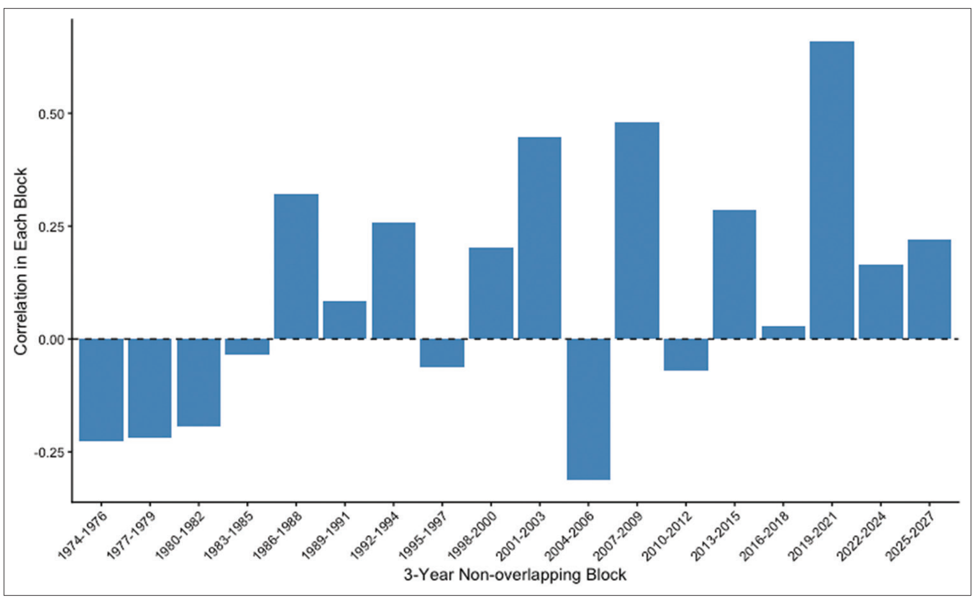
We next examine whether the strength of the oil price-industrial production relationship varies systematically across business-cycle conditions. Figure 4 shows scatter plots of industrial production

Figure 2: 5-year correlations between oil price changes and industrial production growth



The figure plots correlations between monthly oil price changes (p_{t-1}) and industrial production growth (ip_t) calculated using a 5-year non-overlapping window with 60 observations each, except for the first period (7 years from 1974 to 1980) and the last period (last 4 months in 2025 are missing)

Figure 3: 3-year correlations between oil price changes and industrial production growth



The figure plots the correlations between monthly oil price changes (p_{t-1}) and industrial production growth (ip_t), computed over non-overlapping 3-year windows with 36 observations each, except for the final incomplete block covering the first 8 months of 2025

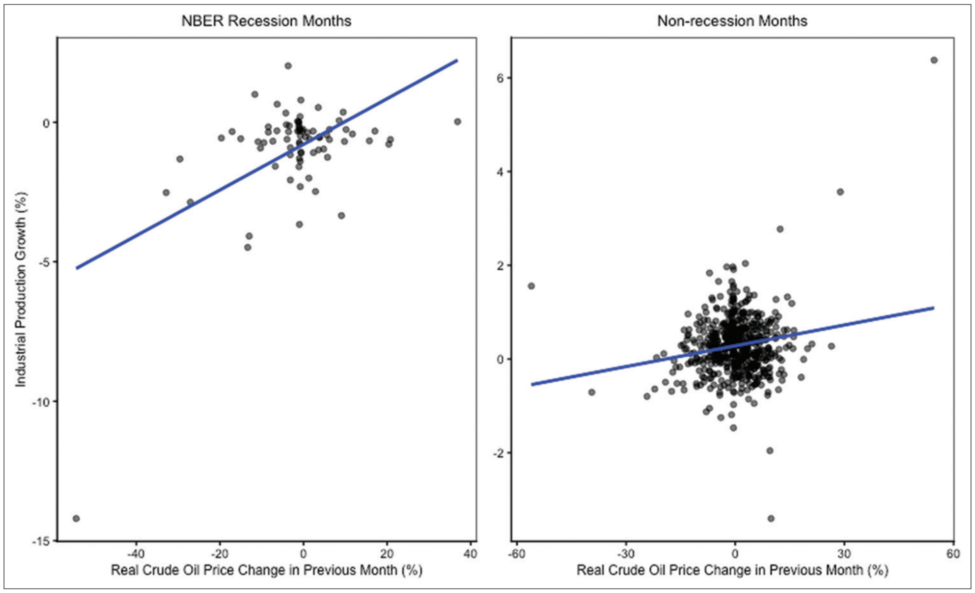
growth (ip_t) against lagged oil price change (p_{t-1}) separately for recession months (77 observations) and non-recession months (541 observations).[1] The slope of the linear regression line in the left panel is noticeably steeper, suggesting a stronger relationship during recessions relative to non-recession periods.

Table 2 reports correlations between oil price changes and industrial production growth conditional on the state of the business cycle. The correlation is substantially higher during recession (0.529) than during non-recession months (0.180). The difference between recession and non-recession periods is 0.349 and this is statistically significant at the 5% level with a right-tailed P = 0.042. This P-value is obtained using moving-block bootstrapping with block length of 12 months and 5,000 bootstrap repetitions. Changing the block length to 24 months does not change the conclusion (P = 0.035).

To ensure that this result is not driven by pandemic-era outliers or by the pre-1985 structural break documented in Section 4.2, we restrict the sample to post-1985 observations, exclude April and June 2020, and test state dependence formally using an interaction

1 Because ip_t and p_t are obtained through first differencing, and ip_t is compared with p_{t-1}, the effective sample size is reduced by two observations from the original 620 months.

Figure 4: Oil price changes and industrial production growth across business-cycle states



The left panel shows the relationship between industrial production growth (ip_t) and lagged real oil price change (p_{t-1}) during recession months. The right panel shows the relationship during non-recession months. Blue solid lines represent linear regression fits

Table 2: Correlation between industrial production growth and lagged real oil price change

Statistic	Recession months	Non-recession months
Correlation	0.529	0.180
(SE)	(0.176)	(0.089)
Observations	77	541

The sample is divided between recession and non-recession months. In each state, the sample correlation coefficient between U.S. industrial production growth (ip_t) and real oil price changes (p_{t-1}) is reported with standard errors in parentheses. Standard errors are obtained by moving-block bootstrapping (block length=12 months, bootstrap repetitions=5,000)

regression. April and June 2020 are excluded because their extreme values reflect pandemic-related administrative shutdowns rather than oil market dynamics.[2] The regression equation is

$$ip_t = \beta_0 + \beta_1 p_{t-1} + \gamma_0 IS\_recession_t + \gamma_1 IS\_recession_t \cdot p_{t-1} + \varepsilon_t \quad (3)$$

where *IS_recession* is an indicator variable that takes the value of 1 for recession months and 0 otherwise.

Table 3 reports the results. The coefficient γ_1 on the interaction between the recession indicator and lagged oil price change (0.024) is positive and statistically significant at the 5% level (P = 0.015 for the right-tailed test), confirming that the correlation is stronger during recessions even after controlling for outliers and the structural break.[3]

Table 3: Regression results with separate intercept and slope for recession months

Variable	Coefficient	Standard Error	P-value	Significance
β_0	0.232	0.027	0.000	***
β_1	0.008	0.003	0.028	**
γ_0	−0.945	0.134	0.000	***
γ_1	0.024	0.011	0.029	**
R^2	0.205			
Number of Obs.	474	Recession	39	
		Non-Recession	435	

This table shows the results of the OLS regression $ip_t=\beta_0+\beta_1 p_{t-1}+\gamma_0 IS\_recession_t+\gamma_1 IS\_recession_t \cdot p_{t-1}+\varepsilon_t$. If the correlation between industrial production growth and lagged oil price change is significantly higher during recession months, the coefficient γ_1 should be positive and significant. The reported P-value for the two-tailed test, based on HAC standard errors, is 0.029, implying that the P-value for the right-tailed test ($\gamma_1>0$) is 0.015. Significance codes: ***0.01, **0.05, *0.1

4.4. Summary of Stylized Facts

Taken together, the reduced-form evidence reveals three key stylized facts. First, real oil prices and U.S. industrial production exhibit positive co-movement on average over the full sample. Second, the strength and sign of the relationship vary markedly over time, with a clear sign reversal around 1985. Third, the relationship is state-dependent, with substantially stronger co-movement during periods of low economic activity.

These patterns motivate a structural analysis that decomposes oil price movements into distinct shocks, allowing the sources of this co-movement to be identified. In addition, the pronounced time variation in the correlation motivates an investigation of whether changes in shock composition can account for the secular shift from negative to positive co-movement.

2 April 2020 saw industrial production fall roughly 14.2% in a single month, and June 2020 saw it rebound roughly 6.4%, both far outside the normal range of the series as shown in Figure I.

3 Including these observations increases the interaction coefficient to 0.074, reinforcing the direction of the main finding, but reduces precision (one-tailed p-value = 0.067), which is consistent with the extreme values adding substantial noise to the regression. The post-1985 correlations, excluding the pandemic outliers, are 0.413 for recession months and 0.110 for non-recession months.

5. STRUCTURAL METHODOLOGY

This section describes the econometric framework used to assess whether the composition of oil price fluctuations (supply shocks, global demand shocks, and oil-specific demand shocks) varies systematically across business-cycle states. The analysis employs a state-dependent structural vector autoregression (SVAR) of the global oil market and focuses on forecast error variance decomposition (FEVD) of real oil prices. The key objective is to test whether global demand shocks (IGREA shocks) contribute more to oil price variability during recessions than during non-recession periods. Such state dependence in shock composition provides a structural explanation for the stronger co-movement between oil price changes and U.S. industrial production growth during recessions documented in Section 4.

5.1. Structural VAR Specification

The empirical analysis is based on a three-variable monthly SVAR that captures the joint dynamics of global oil supply, global demand conditions, and real oil prices. Let y_t denote the vector of endogenous variables,

$$y_t = (\Delta q_t,\ a_t,\ p_t)' \tag{4}$$

where Δq_t denotes the growth rate of global crude oil production (log differences of EIA data on world crude oil production), a_t is global real economic activity measured by Kilian's Index of Global Real Economic Activity (IGREA), and p_t is the logarithm of the real price of oil. The reduced-form VAR of order p is given by,

$$y_t = c + \sum_{i=1}^{p} A_i y_{t-i} + u_t \tag{5}$$

where c is a vector of intercepts, A_i are coefficient matrices, and u_t is a vector of reduced-form innovations. The VAR is estimated over the full sample and includes a constant term. The lag length p is selected using standard information criteria, and robustness to alternative lag choice is examined.

5.2. Identification of Structural Shocks

Structural shocks are identified using a recursive (Cholesky) identification scheme following Kilian (2009). The reduced-form innovations are related to structural shocks ε_t through

$$u_t = B\varepsilon_t \tag{6}$$

where ε_t is a vector of mutually orthogonal shocks with

$$E[\varepsilon_t\, \varepsilon_t'] = I \tag{7}$$

The identifying assumptions imply a lower-triangular structure for B and impose the following contemporaneous restrictions. Global crude oil production does not respond contemporaneously to innovations in global demand or oil prices, reflecting short-run adjustment costs and capacity constraints. Global real economic activity is allowed to respond contemporaneously to oil supply shocks but not to oil price innovations within the month. The real price of oil responds contemporaneously to both oil supply and IGREA shocks.

The identified shocks correspond to (i) oil supply shocks, (ii) IGREA shocks, and (iii) oil-specific demand shocks.

5.3. Forecast Error Variance Decomposition

The primary object of interest is the forecast error variance decomposition (FEVD) of the log real price of oil. For a given forecast horizon h, the FEVD measures the fraction of the h-step-ahead forecast error variance of p_t attributable to each identified structural shock.

Formally, the FEVD for shock j at horizon h is defined as

$$FEVD_j(h) = \left[\sum_{k=0}^{h-1} \left(e_p' \Psi_k B e_j\right)^2\right] \Big/ \left[\sum_{k=0}^{h-1} e_p' \Psi_k B B' \Psi_k' e_p\right] \tag{8}$$

where the numerator is the cumulative volatility in the oil price caused solely by the specific structural shock j, while the denominator is the total forecast error variance of the oil price at horizon h, accounting for the contribution of all structural shocks combined. Ψ_k denotes the moving-average representation of the VAR that describes how the three variables in the VAR evolve following a shock. e_p is a selection vector that isolates the oil price equation from the system of variables, and e_j is a selection vector that isolates the j-th structural shock.

FEVDs are computed separately for recession and non-recession periods. The maximum horizon for FEVD calculation is set to 24 months, which comfortably exceeds the duration of the longest U.S. recession in our sample (18 months). The central focus is on the FEVD share associated with global aggregate demand shocks (IGREA shocks). A higher FEVD share of IGREA shocks during recessions indicates that oil price movements in downturns are disproportionately driven by demand-related forces.

5.4. Interpretation

Before reporting results, we set out the interpretive framework that links FEVD shares to oil price-output co-movement. This ensures that the interpretation is not tailored to the estimates ex post.

The SVAR framework is not used to identify the causal effect of oil prices on U.S. industrial production. Instead, it is employed to characterize how the composition of oil price fluctuations varies across business-cycle states.

We assume that the IGREA shocks influence the oil price and U.S. industrial production in the same direction—higher demand increases both while lower demand decreases both. As for the effects of oil supply shocks and oil-specific demand shocks, we assume they influence oil price and U.S. industrial production in the opposite directions—reduced oil supply or higher oil-specific demand increases oil price but lowers industrial production. These assumptions reflect standard macroeconomic theory and are empirically supported by the FAVAR evidence in De et al.

(2022). They are used only to interpret FEVD results, not to identify shocks.

Table 4 makes clear that when the FEVD share of IGREA shocks is large relative to the other two shock types, oil price movements and output movements are predominantly driven by the same underlying force, producing positive co-movement. Conversely, when oil supply or oil-specific demand shocks dominate, oil prices and output move in opposite directions.

As documented in Section 4, the positive correlation between oil price changes and U.S. industrial production growth is higher during recession months. If FEVD analysis confirms that IGREA shocks account for a larger share of oil price variance during recessions, it provides a structural explanation for this stronger co-movement. This interpretive framework applies to the cross-state comparison (recession vs. non-recession). Whether changes in shock composition also account for the secular shift in the oil price-output correlation over time is examined separately in Section 7.

6. STRUCTURAL RESULTS

This section reports the structural results obtained from the SVAR analysis. The emphasis is on the forecast error variance decomposition (FEVD) of the log real price of oil and, in particular, on whether the contribution of global aggregate demand shocks (IGREA shocks) differs across business-cycle states. These results provide a structural interpretation of the empirical evidence documented in Section 4.

6.1. Baseline FEVD of Real Oil Prices (Full Sample)

We begin with the baseline SVAR estimated over the full sample (from February 1974 to August 2025) using the three-variable Kilian-style oil market system ordered as (Δq_t, a_t, p_t), where Δq_t is global oil production growth, a_t is IGREA (in levels), and p_t is the log real price of oil. The VAR lag length is selected by information criteria: Akaike information criterion (AIC), Bayesian information criterion (BIC), final prediction error (FPE), and Hannan-Quinn information criterion (HQIC). BIC selected P = 2 while the other criteria selected P = 3. Since the results are similar, most of the results are reported with P = 3, which is favored by the majority of information criteria. Although VAR(2) requires nine fewer parameters and may be preferred given the small recession subsample of 78 observations, the qualitatively identical results under both lag lengths reported in Section 6.4 suggest that the degrees of freedom cost of VAR(3) does not materially affect the conclusions.

Table 4: Assumed directional effects of structural shocks

Shock type	Effect on oil price	Effect on IP	Implied co-movement
Oil supply reduction	+	−	Negative
Global demand (IGREA)	+	+	Positive
Oil-specific demand	+	−	Negative

The table summarizes the directional assumptions used to interpret FEVD results. An oil supply reduction refers to an unexpected decrease in global oil production. Implied co-movement refers to the sign of the oil price-output correlation when that shock type dominates oil price fluctuations. These assumptions reflect standard macroeconomic theory and are used only to interpret FEVD results, not to identify shocks

Figure 5 presents the impulse response functions obtained with P = 3.[4] These IRFs are orthogonalized using Cholesky decomposition as explained in Section 5. Note that shocks to IGREA have a positive impact on the log real oil price as expected, and remain significant up until 24 months after the shock.

Table 5 reports the baseline FEVD for the log real price of oil at selected horizons h = {1, 12, 24} for brevity. In the full sample, oil-specific demand shocks dominate oil price fluctuations, especially at short horizons. This pattern is consistent with the unconditional FEVD results reported by De et al. (2022) using a FAVAR framework with sign-restriction identification, suggesting that the dominance of oil-specific demand shocks in the full sample is robust across methodologies. At h = 1, oil-specific demand shocks account for 97.9% of oil price forecast error variance, while oil supply shocks account for 1.5% and IGREA shocks account for only 0.6%. The role of IGREA shocks increases with the forecast horizon, reaching 9.6% at h = 12 and 13.0% at h = 24. Oil supply shocks remain comparatively small (about 3.7% at h = 12 and also at h = 24). The FEVDs in this table are estimated with P = 3. With P = 2, the FEVD values for IGREA decrease slightly to 6.7% at h = 12 and 10.1% at h = 24. Overall, the baseline estimates imply that, on average, IGREA shocks explain a modest but increasing share of oil price variability at forecast horizons of 1-24 months.

Because the full-sample composition of oil price shocks is well established in the literature, these baseline results serve primarily as a benchmark for interpreting the state-dependent decompositions reported next.

6.2. State-Dependent FEVD

The central empirical question concerns whether the composition of oil price fluctuations changes systematically across business-cycle states. To address this question, we partition the sample into recession months ($IS\_recession_t$ = 1) and non-recession months ($IS\_recession_t$ = 0), estimate separate VARs for each subsample using the same three-variable specification and Cholesky identification as the baseline, and compute the FEVDs within each regime. This subsample approach allows both the VAR coefficients and the innovation covariance matrix to differ across business-cycle states. Ninety-percent confidence intervals are constructed using 5,000 residual-resampling bootstrap replications within each regime. These state-dependent results represent a substantial deviation from the full-sample benchmark reported above.

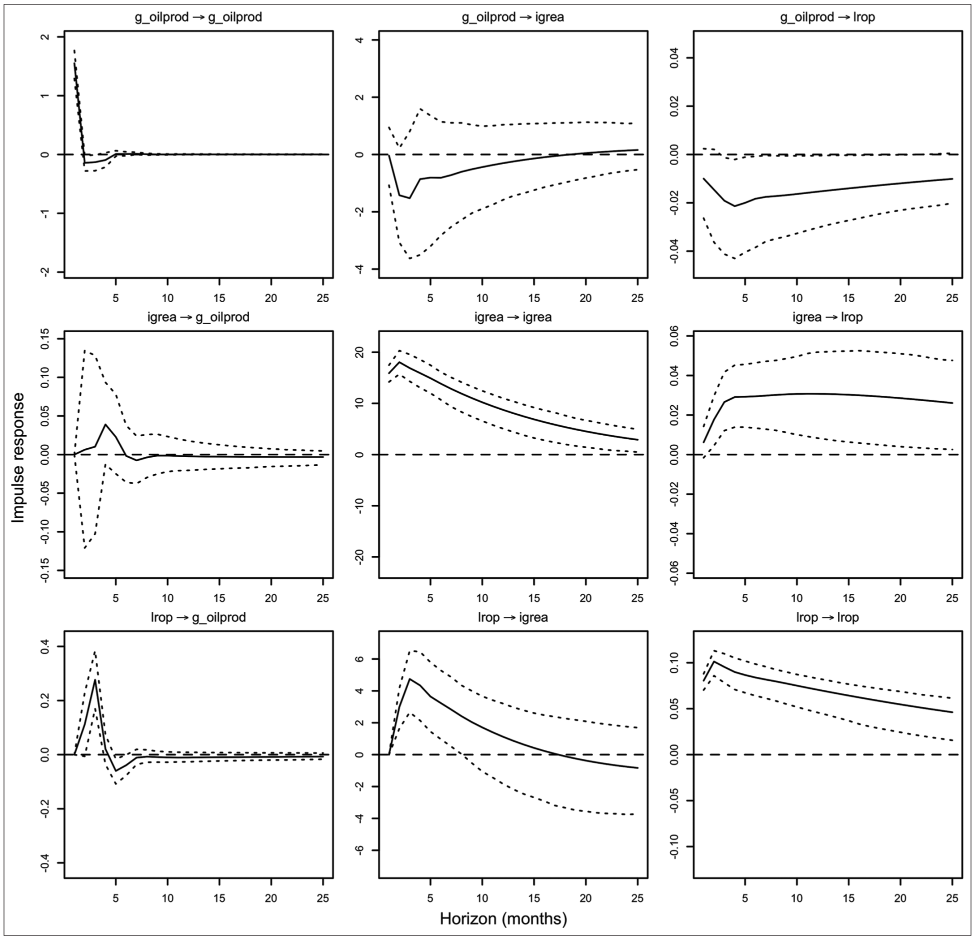
4 IRFs with P = 2 are very similar and not reported.

Table 5: FEVD of log real oil prices (full sample)

Horizon (months)	Oil supply shock (%)	IGREA shock (%)	Oil-specific demand shock (%)
1	1.5	0.6	97.9
12	3.7	9.6	86.8
24	3.7	13.0	83.4

Forecast error variance decompositions (FEVD) for the log real price of oil are computed from the baseline three-variable SVAR estimated over the period from February 1974 to August 2025 with lag length P=3. The VAR is ordered as (Δq_t, a_t, p_t), where Δq_t is global oil production growth, a_t is IGREA (in levels), and p_t is the log real price of oil. Orthogonalized shocks are obtained via Cholesky factorization of the reduced-form innovation covariance matrix

Figure 5: Orthogonalized impulse response functions with P = 3



These IRFs are estimated using the full sample and orthogonalized using Cholesky decomposition. The lag length in the VAR is three, chosen by AIC, HQIC and FPE. Dashed lines represent 95% bootstrap confidence intervals based on 500 replications

The state-dependent FEVD results reveal a pronounced reallocation in the contribution of IGREA shocks during downturns. During recessions (78 months), the IGREA shock explains a substantially larger share of oil price forecast error variance than in non-recession periods (541 months) across all horizons considered.[5] Table 6 shows that the FEVD share of the IGREA shock in recession months is 50.3% at h = 1, 68.6% at h = 12, and 68.5% at h = 24, compared to 5.2%, 8.8%, and 14.4% in non-recession months as reported in Table 7, respectively. The corresponding differences between recession months and non-recession months are 45.1%, 59.8%, and 54.1%. Figure 6 illustrates this difference, with the dotted line showing the IGREA share during recession months and the solid line showing the share during non-recession months. The sizable difference is sustained across all horizons, although it declines gradually over time. The recession FEVD share is notably stable beyond three months, remaining close to 68% from h = 3 through h = 24.

Table 6: FEVD of log real oil prices (recession months)

Horizon (months)	Oil supply shock (%)	IGREA shock (%)	Oil-specific demand shock (%)
1	2.4 (0.0, 13.0)	50.3 (11.9, 74.5)	47.3 (24.5, 80.7)
3	5.3 (0.5, 24.9)	69.0 (28.5, 85.5)	25.7 (11.5, 54.7)
6	10.4 (1.3, 38.3)	68.4 (26.5, 86.0)	21.2 (8.8, 46.2)
12	11.0 (1.6, 38.8)	68.6 (26.2, 86.1)	20.4 (8.4, 46.1)
24	11.1 (1.8, 39.4)	68.5 (25.9, 85.9)	20.4 (8.5, 46.9)

The SVAR specification and Cholesky identification are identical to the baseline in Table 5, but are estimated separately for recession months. Values in brackets report 90% confidence intervals constructed from 5,000 bootstrap replications using residual resampling

Bootstrap confidence intervals reported in Figure 6 indicate that the difference in IGREA shares across regimes is statistically meaningful. At horizons up to approximately 15-16 months, the 90% confidence intervals for the two regimes do not overlap. Beyond this point the intervals begin to overlap, but the point estimates remain substantially different through h = 24, with the recession share exceeding the non-recession share by more than 54% points at the longest horizon considered. The wider confidence intervals for the recession regime reflect the smaller subsample size (78 observations); nevertheless, the lower bound of the recession IGREA share (25.9% at h = 24) exceeds the non-recession point estimate (14.4% at h = 24) at all horizons.

5 Because the growth rate of global crude oil production, Δq_t, is obtained through first differencing, the effective sample size is reduced by one observation from the original 620 months. In Section 4, two observations were lost because ip_t and p_{t-1} require differencing and lagging, leaving 77 recession months in the reduced-form analysis.

Juxtaposed with the baseline benchmark, these state-dependent results imply that the role of IGREA shocks is not merely larger in recessions in absolute terms, but dramatically larger relative to the typical (full-sample) composition of oil price fluctuations. For example, at h = 1, the IGREA share rises from 0.6% in the full sample to 50.3% in recession months; at h = 24, it rises from 13.0% in the full sample to 68.5% in recession months.

6.3. Interpretation

The baseline and state-dependent FEVDs jointly provide a structural interpretation of the patterns documented in Section 4. As documented in prior work and confirmed in the baseline, oil prices are on average largely driven by oil-specific demand shocks, with IGREA shocks playing a modest role that increases at longer horizons. However, during recessions, oil price fluctuations are disproportionately driven by IGREA shocks, indicating a substantial shift in the composition of oil price movements toward demand-related forces.

Because IGREA shocks move oil prices and real activity in the same direction, this state-dependent shift in shock composition provides a structural explanation for why the positive correlation between oil price changes and U.S. industrial production growth is higher during recessions than during non-recession periods. This stronger relationship is in line with the finding of Nonejad (2022).[6] Whether a similar compositional shift accounts for the secular trend toward positive oil price-output co-movement documented in Section 4 is examined using rolling estimation in Section 7.

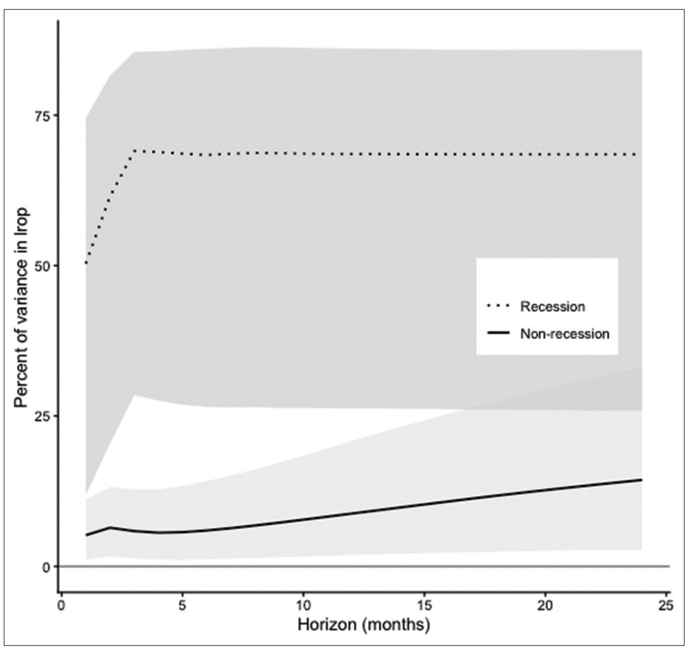
It is notable that during early recessions in the 1970s and the 1980s, even when IGREA shocks accounted for a large share of oil price variance, this high IGREA share did not produce positive oil-output co-movement. This is consistent with a dominant cost channel that prevented demand-driven oil price increases from producing positive co-movement, as discussed in Section 7.

Table 7: FEVD of log real oil prices (non-recession months)

Horizon (months)	Oil supply shock (%)	IGREA shock (%)	Oil-specific demand shock (%)
1	2.3 (0.0, 11.2)	5.2 (1.1, 11.1)	92.5 (82.5, 98.1)
3	1.2 (0.1, 8.8)	5.9 (1.3, 12.8)	92.9 (83.1, 97.7)
6	0.8 (0.1, 7.9)	6.0 (1.2, 14.2)	93.3 (82.4, 97.8)
12	0.5 (0.1, 7.2)	8.8 (1.9, 20.8)	90.7 (76.6, 96.9)
24	0.3 (0.1, 6.9)	14.4 (2.8, 33.1)	85.3 (64.9, 95.7)

Same as Table 6, except that this table reports FEVDs for non-recession months

Figure 6: FEVD share of IGREA shocks by business-cycle state



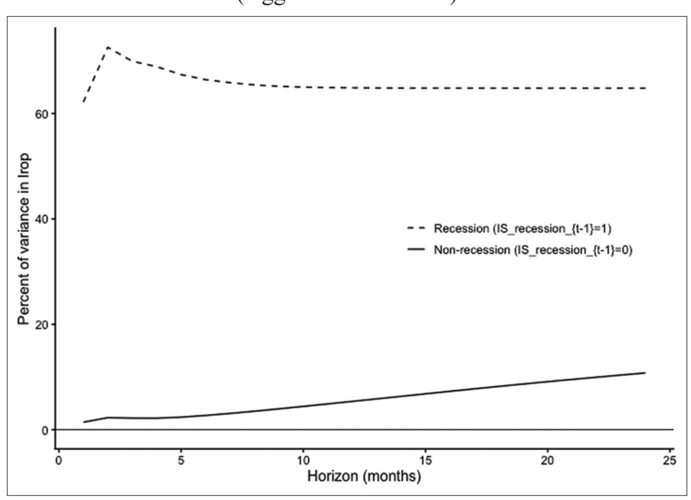
The figure reports the shares of IGREA shocks in the forecast error variance of the log real oil price, estimated using a two-regime SVAR. The regimes correspond to recession months ($IS\_recession_t = 1$) and non-recession months ($IS\_recession_t = 0$). Shaded areas denote 90% confidence intervals

6.4. Robustness

The state-dependent FEVD results are robust to a range of alternative specifications. Re-estimating the SVAR with lag length P = 2 (selected by BIC) rather than P = 3 produces qualitatively identical patterns, with the recession-minus-non-recession differences in the IGREA share remaining large and positive at all horizons. Bootstrap confidence intervals under P = 2 yield the same conclusion: the 90% confidence intervals for the IGREA share in recession and non-recession months do not overlap at horizons of 1-15 months. Replacing the contemporaneous state indicator ($IS\_recession_t$) with its lagged value ($IS\_recession_{t-1}$) to ensure predetermined state classification leaves the results unchanged, as shown in Figure 7. These checks confirm that the main finding—a pronounced shift in the composition of oil price fluctuations toward IGREA shocks during recessions—is

6 Nonejad (2022) documents that the out-of-sample predictive power of oil prices for U.S. industrial production is concentrated in oil price declines rather than increases. This finding is consistent with the state-dependent results reported here, since oil price declines tend to coincide with recession periods when global demand shocks account for a larger share of oil price fluctuations.

Figure 7: FEVD share of IGREA shocks by business-cycle state (lagged state indicator)



This figure replicates the analysis in Figure 6 using the lagged recession indicator ($IS\_recession_{t-1}$) in place of the contemporaneous indicator ($IS\_recession_t$). The results are virtually unchanged not sensitive to lag length, forecast horizon, or the timing of the state indicator.

7. ROLLING EVIDENCE ON DEMAND SHOCKS AND OIL-OUTPUT CO-MOVEMENT

This section examines whether changes in the importance of IGREA shocks can account for the evolving relationship between real oil prices and U.S. industrial production. We compare a rolling correlation between U.S. industrial production growth and lagged real oil price change with a rolling measure of the contribution of global real activity shocks to oil price fluctuations, computed from a Kilian-style structural VAR.

7.1. Rolling Correlation and Rolling FEVD Share

We construct a rolling correlation between industrial production growth and lagged real oil price change using a moving window. In parallel, we estimate a three-variable SVAR consisting of global oil production growth, global real activity (IGREA), and the log real price of oil over the same rolling windows, and compute the forecast error variance decomposition share (FEVD share) of oil price fluctuations attributable to the IGREA shock at a 6-month horizon. This horizon is chosen to balance two considerations: it is long enough to capture meaningful shock transmission while remaining well within the duration of a typical U.S. recession, which averages roughly 11 months in our sample, and it corresponds approximately to the midpoint of that average duration.

Figure 8 presents the rolling analysis using a 10-year window. This window length offers a balance between sufficient smoothing for readability and enough independent variation to assess co-movement between the two series. The oil price-output correlation (thick blue line) begins negative around −0.15 in the mid-1980s, crosses zero near 1990, and then fluctuates in positive territory for the remainder of the sample, with peaks that tend to coincide with recession periods. The IGREA FEVD share (thin orange line) is considerably more volatile, swinging from near zero to above 40%, with the most prominent spike occurring around the great recession period.

Figure 9 presents the same analysis using a 5-year window, which reveals dynamics in earlier periods. Both series are highly volatile at this frequency, but several features are informative. In the pre-1990 period, the IGREA FEVD share is sometimes high while the oil price-output correlation is negative, illustrating that a large contribution of IGREA shocks to oil price variance did not produce positive oil-output co-movement when the cost channel was dominant. After 2001, episodes of apparent co-movement between the two series emerge, concentrated around major global downturns such as the Great Recession and the COVID-19 pandemic. However, outside these episodes, the two series frequently diverge.

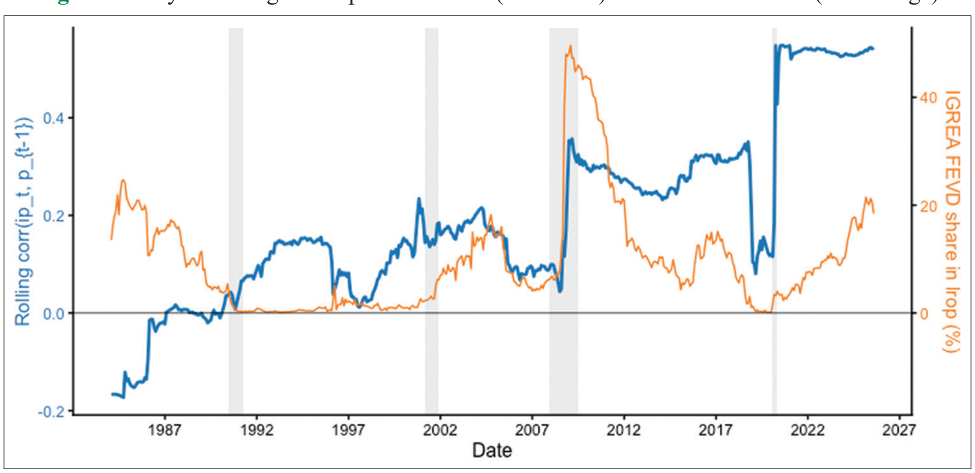
7.2. Three-Phase Interpretation

Inspection of Figures 8 and 9 reveals three distinct phases in the relationship between IGREA shocks and oil-output co-movement.

7.2.1. Phase 1 (pre-1990)

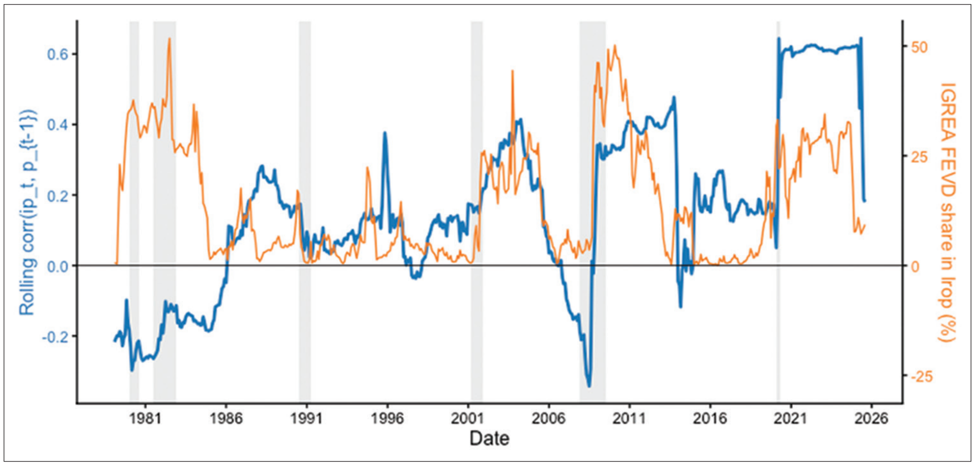
The oil price-output rolling correlation is predominantly negative, and the IGREA FEVD share at times moves in the opposite direction. During this period, oil price fluctuations were heavily influenced by supply disruptions (the 1970s oil crises, the Iran-Iraq War) and by oil-specific demand forces. Even when IGREA shocks contributed meaningfully to oil price variance, they did not produce positive oil-output co-movement because a strong cost channel caused demand-driven oil price increases to simultaneously depress U.S. output. The pre-1990 period thus illustrates that shock composition alone is insufficient to determine the sign of the oil price-output relationship; the transmission regime matters as well.

Figure 8: 10-year rolling oil-output correlation (thick blue) versus IGREA share (thin orange)



The figure plots the rolling correlation between U.S. industrial production growth and lagged real oil price change (thick blue line, left axis) together with the rolling forecast error variance decomposition (FEVD) share of real oil price fluctuations attributable to global real activity (IGREA) shocks (thin orange line, right axis). Rolling correlations and FEVD shares are computed using a 10-year window. FEVD shares are computed at a 6-month horizon from a three-variable SVAR ordered as global oil production growth, global real activity, and the real oil price. Shaded areas indicate NBER recession periods

Figure 9: Rolling correlation (thick blue) versus IGREA share (thin orange), 5-year window



This figure repeats the rolling analysis using a shorter 5-year window and a 6-month FEVD horizon. The shorter window produces more volatile series but reveals dynamics in the pre-1990 period that are not visible with longer windows

7.2.2. Phase 2 (1990-2001)

The oil price-output correlation turns positive, but the IGREA FEVD share does not yet co-move with it. This suggests that the initial sign reversal was driven primarily by structural changes in oil price transmission—reduced energy intensity, improved monetary policy during the Great Moderation, and declining oil intensity of production—rather than by a shift in the composition of oil price shocks. These transmission changes weakened the contractionary effects of oil price increases regardless of their source, consistent with the findings of Blanchard and Galí (2009).

7.2.3. Phase 3 (post-2001)

The rolling correlation and the IGREA FEVD share display episodes of co-movement, most prominently during the Great Recession and the COVID-19 pandemic. This pattern is consistent with the deepening of global economic integration following China's WTO accession in December 2001, which made global demand a more distinct external force acting on the U.S. economy. Through expanded trade linkages and global supply chains, these external demand shocks could independently pull both oil prices and U.S. industrial production in the same direction. However, outside these major downturns, the two series frequently diverge. In particular, the IGREA FEVD share does not exhibit a secular upward trend while the oil price-output correlation continues to drift upward. As shown in Figure 9, the IGREA share spikes during recessions and subsides afterward, a pattern that is more visible at the 5-year window than at the 10-year window due to the smoothing effect of the longer rolling window.

7.3. Assessment of the Rolling Evidence

The IGREA FEVD share does not account for the secular increase in the oil price-output correlation. The IGREA share behaves as a cyclical variable—spiking during downturns and reverting afterward—rather than as a trend variable. The secular sign reversal in the oil price-output correlation occurs around 1990 or earlier, a period when the IGREA share is low and relatively stable, pointing to structural transmission changes as the primary driver. Transmission changes account for the sign reversal around 1990, and the IGREA share accounts for recession-linked amplification, but the continued strengthening of positive co-movement in recent decades is only partially explained by the forces identified in this paper and likely reflects additional structural forces—possibly including the shale revolution, which made the U.S. a major oil producer and created channels through which oil price increases boost domestic output, deeper trade integration that transmits global demand shocks through channels beyond what the IGREA index captures, or other factors—that are beyond the scope of the current analysis.

8. CONCLUSION

This paper examines the evolving relationship between oil prices and U.S. industrial production using a combination of reduced-form analysis, structural decomposition, and rolling estimation. The reduced-form evidence documents three stylized facts: the correlation between oil price changes and industrial production growth is positive for the full sample; the correlation is negative in the earlier part of the sample but becomes increasingly positive after the mid-1980s; and the relationship is substantially stronger during periods of low economic activity.

To interpret these patterns, the paper employs a structural VAR framework of the global oil market and focuses on forecast error variance decomposition of oil prices. Consistent with existing evidence, the full-sample composition of oil price fluctuations is dominated by oil-specific demand shocks, with global aggregate demand shocks playing a relatively modest role. However, during periods of pronounced economic weakness, the composition of oil price shocks tilts toward global demand forces. This pattern of variation across recession and non-recession periods in the relative importance of global demand shocks (IGREA shocks) helps explain why the positive co-movement between oil prices and industrial production becomes more pronounced during economic downturns.

Rolling estimation reinforces the distinction between cyclical and secular drivers of oil price-output co-movement. The IGREA FEVD share accounts well for the stronger positive correlation observed during recessions but does not trend upward over time, implying that it cannot explain the secular shift from negative to positive co-movement. That shift appears driven primarily by structural transmission changes that weakened the cost channel by the early 1990s. The continued strengthening of positive co-movement in subsequent decades remains only partially explained and likely reflects additional structural changes—such as the shale revolution and deeper global trade integration—that warrant further investigation.

These findings do not contradict earlier results, such as Hamilton (1983), emphasizing the contractionary effects of oil supply disruptions. Rather, they show that the dominant source of oil price fluctuations varies over time and across business-cycle states, and that the correlation coefficients reflect a mixture of fundamentally different shocks. The observed positive co-movement during low-activity periods does not imply that higher oil prices stimulate real economic activity; instead, it reflects joint responses of oil prices and real activity to underlying global demand conditions.

This distinction carries practical implications for real-time interpretation of oil price movements. During downturns, oil price increases are more likely to reflect improvements in global demand conditions than adverse supply shocks. Conversely, oil price declines during these periods may signal weakening demand rather than favorable supply developments. More broadly, the interpretation of oil price movements depends not only on business-cycle state but also on the structural regime governing oil price transmission and the degree of global economic integration.

The results highlight the limitations of analyses that rely solely on reduced-form relationships or average effects. Structural decomposition that accounts for heterogeneity across business-cycle states is essential for understanding how oil prices interact with real activity. The prominent role of IGREA shocks during downturns underscores the importance of global factors in shaping domestic economic outcomes, while the incomplete explanatory power of these shocks for the secular trend points to avenues for future research.

Future research could extend the analysis by incorporating time-varying parameter models to formally estimate changes in the strength of the cost channel over time, examining the role of the shale revolution in altering the domestic transmission of oil price movements, employing alternative measures of global demand, or using cross-country data to further explore how the sources of oil price fluctuations and their transmission mechanisms evolve across different structural regimes.

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