Has the relationship between the oil market and the US economy changed? A local projection approach

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Abstract

This paper studies whether the macroeconomic effects of oil market shocks on the economy in the United States have changed over time. Building on the structural decomposition of the oil market proposed by [Kilian, 2009], we first replicate and update the identification of oil supply, aggregate demand, and oil-specific demand shocks using a monthly structural VAR, with data extending through August 2025. We then use the local projection method [Jordà, 2005] to obtain impulse response functions for GDP growth, inflation, and monetary policy across two periods: 1975-1985 and 1985-2024. The former represents the era before "the great moderation", the latter represents the era that comes after. Additionally, to account for the zero lower bound on nominal interest rates in the period after 1985, we perform this analysis twice. Once using the Federal Funds rate to reflect monetary policy and once using a shadow rate as derived in [Wu and Xia, 2016]. The results indicate that the macroeconomic relationship between the oil market and the US economy differs substantially across periods, with generally weaker and less persistent effects in the post-1985 era. The results seem robust to the different measures reflecting monetary policy.

1 Motivation

The relationship between oil prices and economic growth has long interested economists. It is believed that increased oil prices have contractionary effects on the real economy (GDP). However, currently there is some contention on the stability of this relation. It is observed that more recent disturbances in the oil market, which resulted in similar price hikes, did not have the same level of effect or persistence as the ones in the 1970s, which caused a period of stagflation in the US economy. Some authors argue that due to structural changes in the economy such as a shift from manufacturing industry to service industry, superior monetary policies and advances in energy efficiency, the dependence on oil for economic growth has weakened [Blanchard and Galı, 2007]. At the same time others argue that the oil-GDP linkage has not weakened. Instead, differences in outcomes are due to misidentified shocks in the oil market [Hamilton, 1996], [Kilian, 2009]. The goal of this text is to investigate the evolution of the effect of disturbances in the oil market on the activity level of the US economy. We do this building on critical existing literature and methods such as [Kilian, 2009], and [Jordà, 2005].

Understanding which explanation holds more truth has important policy implications, especially with current debates about energy transitions. If the economy has genuinely become less vulnerable to oil shocks, policymakers can act accordingly and shift some focus and resources away from energy security and price stabilization initiatives. Additionally, these findings would influence debates about energy transition and climate policy. If reduced oil vulnerability is a consequence of structural changes like improved energy efficiency and sectoral shifts, this suggests that further investments in clean energy and energy efficiency may continue to decouple economic performance from fossil fuel markets. This would strengthen the economic case for aggressive climate policies and renewable energy transitions, as they would both reduce carbon emissions and economic dependency on external factors and countries influencing the oil market.

This paper contributes to this debate by combining the structural identification approach of [Kilian, 2009] and a comparison across time periods. We update Kilian's shock identification with recent data up through august 2025 and using updated software. We insert these orthogonal shocks into local projection model to test whether impulse response functions differ between pre-1985 and post-1985 eras.

Additionally, we provide discussion on an issue that, to the best of our knowledge, is largely absent from earlier work but critical for the post-2008 period: the zero lower bound on nominal interest rates. From December 2008 through December 2015, and again from March 2020 through March 2022, the Federal Reserve held the federal funds rate at zero or close to it, while further implementing expansionary policy through other means such as quantitative

easing. We address this issue by estimating our models twice: once with conventional federal funds rates and once with the Wu-Xia shadow federal funds rate [Wu and Xia, 2016]. The shadow rate extends into negative territory to capture the stimulative stance of unconventional policies, providing a more complete reflection of monetary policy when the interest rates were at the zero lower bound. Comparing these results allows us to assess whether our conclusions are robust to how we measure monetary policy.

2 Data

Our analysis combines data from multiple sources, different frequencies and sample periods. This section contains different subsections associated with the parts of our analysis. A subsection describes each data series that was used in that part of the analysis together with its source, frequency, the transformation applied to the data and sample period.

2.1 Replication of Kilian's structural shock

The structural identification of oil shocks follows [Kilian, 2009] and requires three monthly variables:

Global Crude Oil Production: We download monthly world crude oil production data from the U.S. Energy Information Administration (EIA). The series measures total global crude oil supply in thousands of barrels per day. Following [Kilian, 2009], we transform this series by taking the log difference and multiplying it by 100 to obtain the percentage change in oil production. The data ranges from 1973-01-01 to 2025-08-01. Name of the file: EIA_oilprod_cleaned.csv
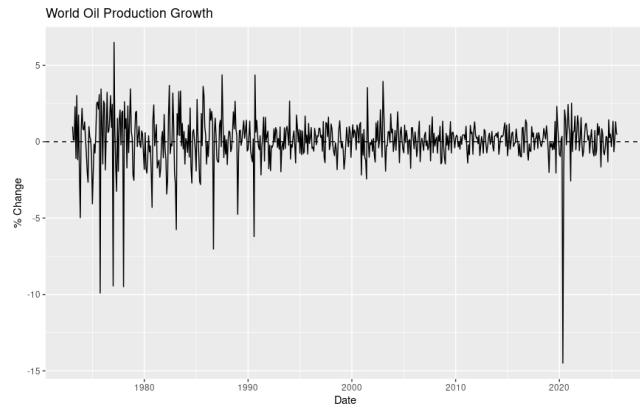

Figure 1: Exploratory visual: percentage change of oil production

Kilian Index of Global Real Economic Activity: This index, constructed by Lutz Kilian, measures monthly global real economic activity based on dry cargo shipping freight rates. It is maintained by the Federal Reserve bank of Dallas and can be downloaded from their site. The sample period ranges from 1968-01-01 to 2025-11-25. Name of the file: igrea.xlsx
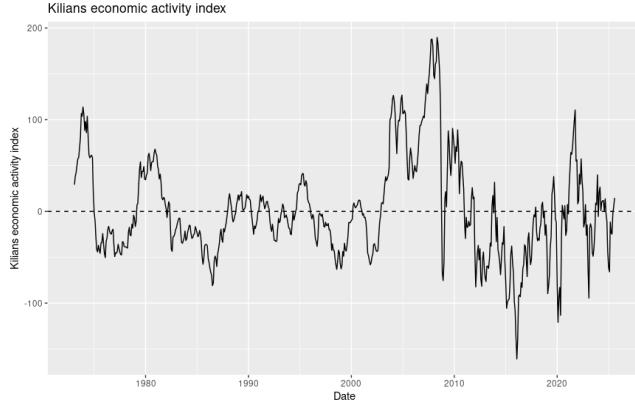

Figure 2: Exploratory visual: Kilian's index for World real activity

Real Price of Crude Oil: We use the West Texas Intermediate (WTI) spot price as our nominal oil price measure, obtained from the Federal Reserve Economic Data (FRED) database (series: WTISPLC). To convert to real terms, we deflate using the Consumer Price Index for All Urban Consumers (CPI-U, series: CPIAUCSL, also from FRED). We then take the logarithm. The sample period for the real oil price ranges from 1946-01-01 to 2025-11-01. Name of the files: WTISPLC.csv and CPIAUCSL.csv.
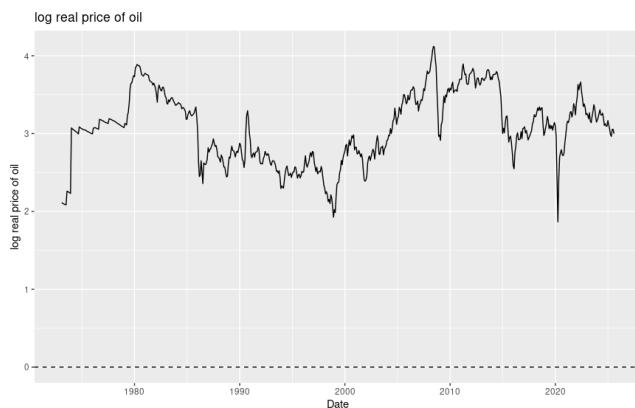
Figure 3: Exploratory visual: logarithm of real price of oil

We compare the shocks we have identified with the original shocks as obtained in [Kilian, 2009]. To get these shocks, we downloaded the replication file from Kilian's website and ran it in matlab. We obtained the original monthly structural shocks and named the file: kilian_monthly_shocks_extracted.csv . The shocks range from 1975-02-01 to 2007-12-01.

2.2 Local Projection

The local projection analysis requires macroeconomic data that is only available on a quarterly basis. Therefore, all the other variables that are on a monthly basis, such as the structural shocks we identified, will be aggregated to a quarterly basis by averaging over the months in a quarter.

Real GDP Growth: We obtain real GDP (in billions of chained 2017 dollars) from FRED (series: GDPC1). We compute the growth as $100 \times [\log(GDP_t) - \log(GDP_{t-1})]$. The GDP growth series ranges from 1947-03-01 to 2025-09-01.
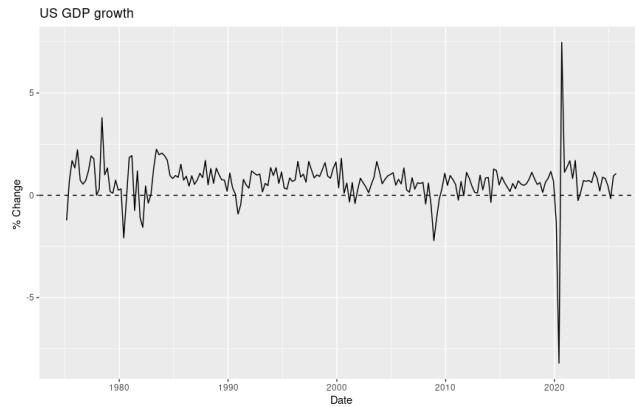

Figure 4: Exploratory visual: US GDP growth

Inflation: We measure inflation using the same CPI series as for recreating the structural shocks (CPIAUCSL). This series is monthly, so first we aggregate to quarterly CPI. Afterwards, we define the quarterly year-on year inflation rate as $100 \times \frac{CPI_t - CPI_{t-4}}{CPI_{t-4}}$. Where the periods t denote quarters.

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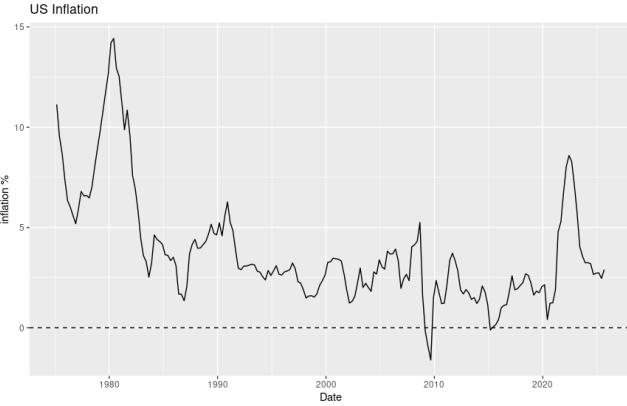
Figure 5: Exploratory visual: Inflation, US CPI growth

Federal Funds Rate:: The federal funds rate is the interest rate at which depository institutions trade federal funds (balances held at Federal Reserve Banks) with each other overnight. We use the FEDFUNDS series from FRED. This series is available from 1954-07-01 till 2025-11-01. It is recorded monthly so we aggregate it to quarterly as discussed before.
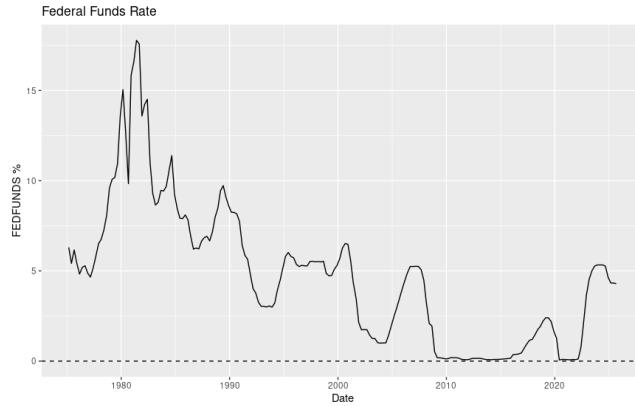

Figure 6: Exploratory visual: Federal Funds rate

Shadow Federal Funds Rate: The Wu-Xia shadow rate extends the concept of the federal funds rate below zero to capture the impact of unconventional monetary policy. It represents the level at which the federal funds rate would need to be set (potentially negative) to achieve the same economic stimulus as the combination of conventional and unconventional policies in place [Wu and Xia, 2016]. We downloaded WuXiaShadowRate.xlsx from the Federal Reserve Bank of Atlanta. It contains the regular interest rate (FEDFUNDS) and the shadow rate starting from 1990. For time periods before we assume

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that the shadow rate is equal to the federal funds rate. Under this assumption this series ranges from: 1960-03-01 to 2022-02-01.
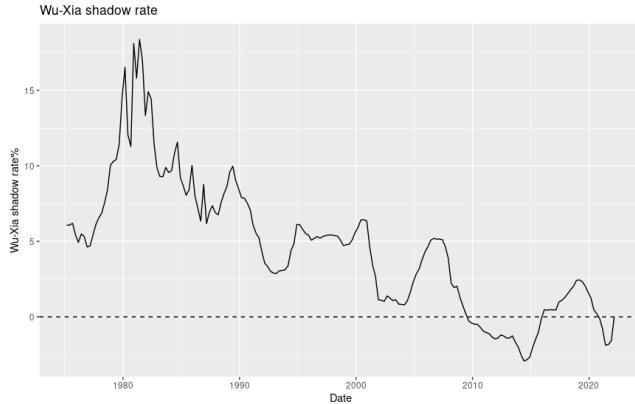

Figure 7: Exploratory visual: Wu-Xia Shadow rate

3   Methodology and Estimation

Our methodology proceeds in three steps. First we identify the structural shocks as found in [Kilian, 2009]. Afterwards we use the local projection method as proposed in [Jordà, 2005] to obtain impulse response functions of those shocks on the macroeconomic variables of interest. Finally we repeat the second part of the analysis using the shadow rate from [Wu and Xia, 2016] to check if our results are robust for different measures reflecting monetary policy. In this section we explain our model and show the results obtained through the estimation.

3.1   Replication of structural shocks

Early works on oil and the macro economy often used simple measures like "percentage change in oil prices" or "oil price increases above recent trends". However, using these measures does not fully reflect the more complex mechanisms that determine price, potentially leading to spurious conclusions. Oil price movements reflect different underlying shocks with distinct macroeconomic implications. [Kilian, 2009] was a highly influential paper that disentangles these mechanisms and identifies three different types of shocks: oil supply shocks, shocks in oil-specific demand and shocks in aggregate demand for oil. The identified shocks are orthogonal and well-established in the literature, making them suitable inputs for local projection analysis. The shocks are obtained via a structural VAR using global input data. Following the same variables, amount

of lags (24) and identification (Cholesky), the structural VAR becomes:

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

Where $z_t = (\Delta prod_t, rea_t, rpo_t)$, where $\Delta prod_t$ is the percent change in global crude oil production, rea_t denotes the index of real economic activity and rpo_t refers to the real price of oil. All as discussed in the data section. Cholesky identification implies that A_0^{-1} is a lower triangular matrix. We compare our results with the original shocks from the paper [Kilian, 2009]. Our replication extends to 2025, while Kilian's data stops at 2007, we plot both shocks with ours extending past 2007.
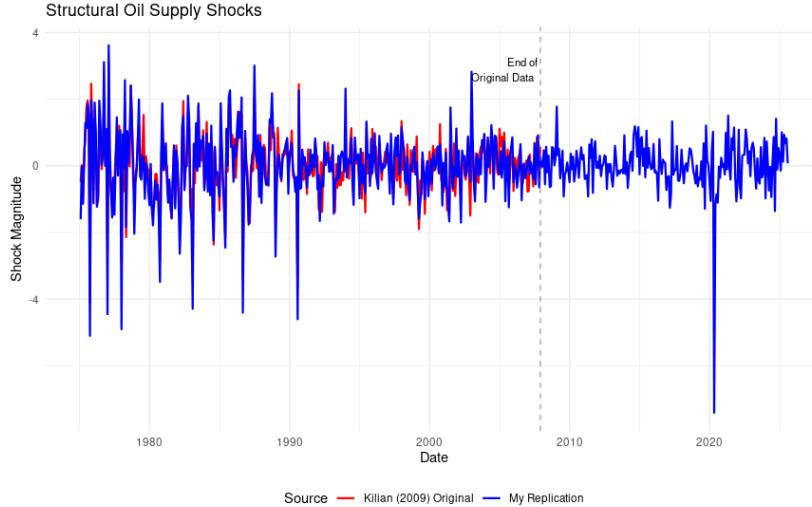

Figure 8: Comparison of structural oil supply shocks.

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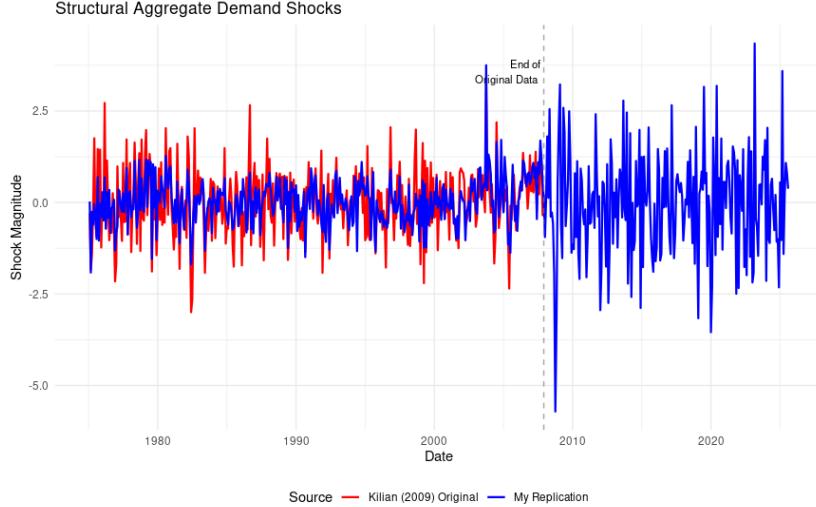
Figure 9: Comparison of structural aggregate oil demand shocks
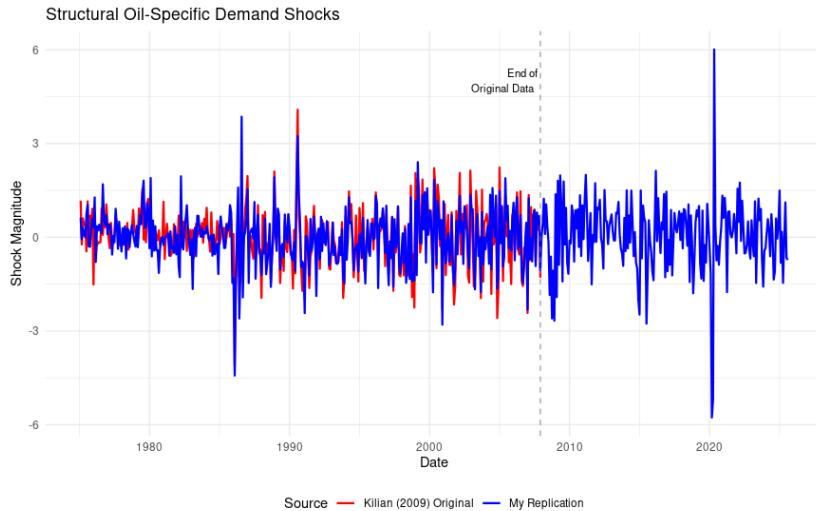
Figure 10: Comparison of structural oil-specific demand shock

We see that red and blue lines are similar in the overlapping period. However, there are some differences. These differences are caused by multiple reasons: We use updated datasets with more observations that include the pandemic period, we use updated software and the standardization of our structural shocks is different. Our shocks are standardized to have a standard error of 1, while, for some reason, Kilian's shocks are scaled to have a standard error of 0.9040237.

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Another interesting observation is how structural shocks spike around 2020. This is a good sign pointing towards meaningful shocks, as one would expect the COVID-19 pandemic to cause major shocks to oils markets. To further examine the success of our replication we also compute the correlations between our structural shocks before 2007 and the original shocks produced in [Kilian, 2009].

Table 1: Correlation Between Recreated and Original Kilian Shocks (1973-2007)

Shock Type	Correlation Coefficient
Oil Supply Shock	0.870
Aggregate Demand Shock	0.688
Oil-Specific Demand Shock	0.791

Despite these different factors we mentioned, the correlations seem to be sufficiently high to call the replication a success and to proceed with these shocks for the further analysis and local projections.

3.2 Local projections

Since we now already have identified orthogonal exogenous shocks, we can estimate impulse response functions using the local projection method [Jordà, 2005]. This approach holds several advantages. One of the advantages is that it is quite straightforward to estimate the impulse response function and to get correct standard errors. To account for heteroskedasticity and autocorrelation, we use the corrected standard errors as proposed by [Newey and West, 1987]. Another advantage is how it allows us to test whether the impulse response functions of the two periods are significantly different in a simple and clear-cut way, by defining an interaction variable and testing this coefficient for significance (more detailed explanation follows).

3.2.1 Model

We estimate the following regression models:

$$y_{i,t+h} = \theta_{i,j,h}\epsilon_{j,t} + \Gamma_{i,t}X_{i,t} + \xi_{t+h}$$

In this equation the y variables are GDP growth, inflation and federal funds rate in quarter t respectively. The ϵ variables are the structural shocks in quarter t as identified earlier, in order they are: oil supply shock, aggregate demand shock and oil-specific demand shock. $X_{i,t}$ are the control variables for $y_{i,t}$. The control variables for a dependent variable y_i are themselves lagged for the past 4 periods and the other dependent variables lagged for the past 2 periods. We chose this asymmetric structure of lags because we want to make a tradeoff between parsimony and flexibility. We consider that a dependent variable's own lags are more important than those of other control variables: A variable's recent history is typically its best predictor. GDP growth this quarter

strongly predicts GDP growth in the next quarter, inflation this quarter strongly predicts inflation next quarter and so on. Including four lags of the dependent variable ensures we adequately capture this persistence. Including many lags of all control variables would quickly exhaust degrees of freedom, especially in our pre-1985 sample which is smaller compared to the post-1985 sample. By using four lags of the dependent variable but only two lags of the other controls, we capture the most important dynamics while keeping the model estimable and avoiding overfitting. The specific control variable selection is as follows:

- **For GDP growth as dependent variable:**
    - 4 lags of GDP growth
    - 2 lags of inflation
    - 2 lags of monetary policy (here Federal Funds rate, later shadow rate)

- **For inflation as dependent variable:**
    - 4 lags of inflation
    - 2 lags of GDP growth
    - 2 lags of monetary policy (here Federal Funds rate, later shadow rate)

- **For monetary policy as dependent variable (here Federal Funds rate, later shadow rate):**
    - 4 lags of monetary policy (here Federal Funds rate, later shadow rate)
    - 2 lags of GDP growth
    - 2 lags of inflation

As for the length of the horizon of the impact of shocks (h), we chose a maximum of 12 quarters, which translates to 3 years. This horizon is consistent with standard literature, including [Jordà, 2005] and [Kilian, 2009]. Opting for this horizon makes our results directly comparable to theirs.

3.2.2   Estimation and Results

We split our data sample into two different periods: 1975-1985 and 1985-2025. Then, for each period, we estimate the local projection model for all combinations of outcome variables (i $\in$ GDP growth, inflation, fed funds), shock types (j $\in$ supply, demand, oil-specific), and horizons (h $\in$ 0, ..., 12), yielding $3 \times 3 \times 13 = 117$ estimated impulse response coefficients per period. We extract the coefficients and construct 95% confidence intervals taking into account heteroskedasticity and autocorrelation using Newey and West standard errors [Newey and West, 1987]. Figures 11-13 display the estimated impulse response functions, with red shaded regions representing the pre-1985 period and blue shaded regions representing the post-1985 period.

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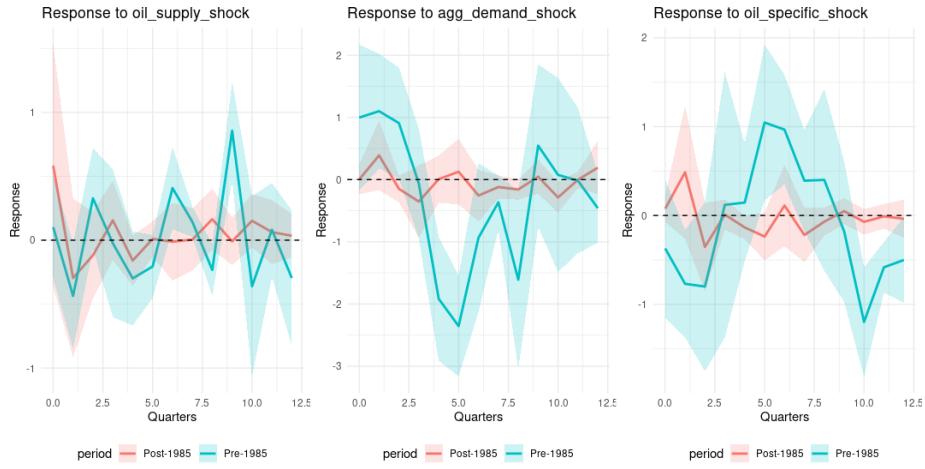
Figure 11: Response of GDP growth to supply shock (left), aggregate demand shock (middle), oil-specific demand shock (right)
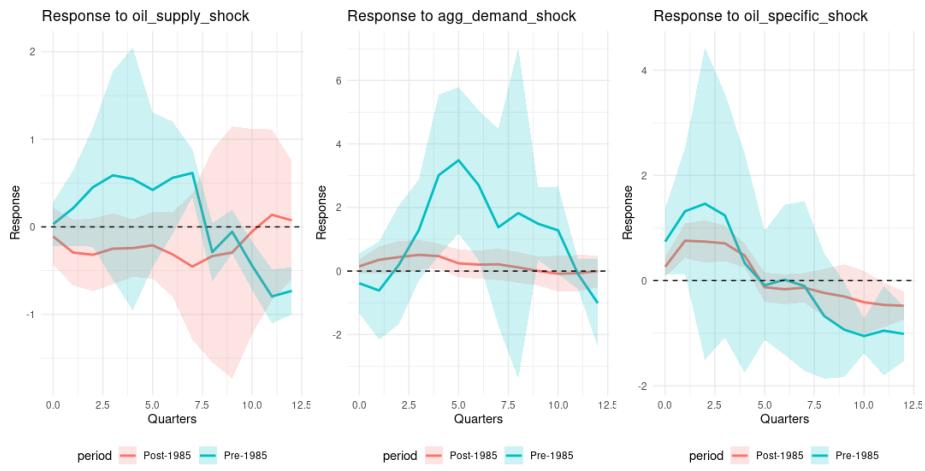
Figure 12: Response of Inflation to supply shock (left), aggregate demand shock (middle), oil-specific demand shock (right)
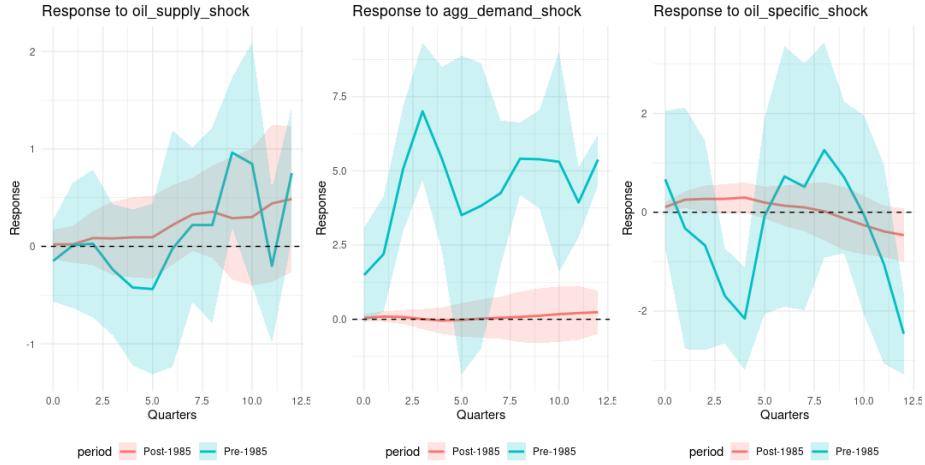
Figure 13: Response of Federal funds rate to supply shock (left), aggregate demand shock (middle), oil-specific demand shock (right)

A first inspection of the plots tells us that almost all impulse response functions of the pre-1985 era (red confidence bands) are a lot more centered around zero than the response functions of the post-1985 time period (blue confidence bands). This is the first evidence supporting the "great moderation" argument, suggesting that the impact of disturbances in the oil market on the US economy has weakened and has become less persistent. However, the confidence intervals are rather wide and overlap for some periods and impulses. To get a clearer overview we will introduce a more formal test comparing the two periods.

3.2.3 Comparison using interaction term in local projection

To formally test for which dependent variable, shock, horizon combination the impulse response function is significantly different we add an interaction term to our local projections, so that the model becomes:

$$y_{i,t+h} = \theta_{i,j,h}\epsilon_{j,t} + \Gamma_{i,t}X_{i,t} + \delta_{i,j,h}\gamma_{j,t} + \xi_{t+h}$$

Where $\gamma_{j,t}$ is equal to zero if quarter t is before 1985 and is equal to $\epsilon_{j,t}$ if it is after 1985. If the coefficient of this term: $\delta_{i,j,h}$, is significant (the confidence interval does not contain zero) we can infer that the response of shock j, on variable i, for horizon h is significantly different across the two periods. Table 2 gives a summary of which responses are significantly different.

Table 2: Significant IRF Differences Across Periods

Response	Shock	Significant Horizons		Horizons
		N	%	
Interest Rate	Agg. Demand	7	53.8	0–6
	Oil-Specific	7	53.8	6–12
	Supply	0	0.0	–
GDP Growth	Agg. Demand	5	38.5	4–8
	Oil-Specific	5	38.5	5–6, 10–12
	Supply	0	0.0	–
Inflation	Agg. Demand	0	0.0	–
	Oil-Specific	11	84.6	0, 3–12
	Supply	4	30.8	7–10

Notes: Analysis based on 13 quarters (horizons 0-12). Significant differences identified when 95% confidence intervals of the interaction term exclude zero, indicating the impulse response differs significantly between the pre-1985 and post-1985 periods.

From this table, we can infer a couple of things:

Oil supply shocks: Out of the three different kind of structural shocks, the shocks where there is the least amount of evidence of having different impact across the two different periods are oil supply shocks. Furthermore, we see that there are no significant differences in the relationship between oil supply and inflation or GDP growth. This gives further strength to arguments in [Kilian, 2009] that the structural relationship between oil-supply and US macroeconomic variables, especially GDP growth, has not significantly changed compared to the pre- "great moderation" era.

Monetary policy and inflation: We can infer that monetary policy reactions to oil demand shocks now significantly differ from the pre-1985 era. For both aggregate demand shocks and shocks in oil-specific demand, the interest rate response differs significantly across periods for more than half of the horizons (53.8%). For aggregate demand shocks this is concentrated in the short to medium run (horizons 0–6) and for oil-specific demand shocks this is concentrated in the medium to long run. This suggests that the Federal Reserve has changed its responses to disturbances in the global oil market. When we combine this with the largely significant differences for inflation, this would be a strong argument for claiming that the Federal Reserve now implements superior policy, which has reduced the impact of oil-market shocks on the US economy.

GDP growth: There are also quite a few significant differences when we look at demand shocks, both oil-specific and aggregate demand, affecting GDP growth. The significant horizons are mostly in the medium to long term: one

year to three years. This would indicate that compared to the pre "great moderation" era, the persistence of oil demand shocks has significantly decreased in recent decades.

3.3   The effect of Shadow rates

3.3.1   Motivation

Up till now we have incorporated the Federal Funds rate in our models to reflect the dimension of monetary policy. However, this measure has an important limitation for the post-1985 period. During this period, there were times, such as after the financial crisis and during the COVID-19 pandemic, when the Federal Reserve maintained the Federal Funds rate at or near zero while taking other unconventional measures to pursue expansionary policy such as quantitative easing (QE). The Federal Funds rate fails to capture this additional policy: A Federal Funds rate of 0.25% during the QE period does not reflect the same policy stance as 0.25% in normal times when QE is absent. This could potentially bias our conclusions about how oil shocks affect the economy in the post-1985 period, if we do not take this into account. To address this concern, we re-estimate all local projections from Section 3.2 using the Wu-Xia shadow Federal Funds rate [Wu and Xia, 2016] instead of the conventional Federal Funds rate. The shadow rate extends below zero to capture the stance of unconventional policy, providing a more complete measure of monetary conditions.

3.3.2   Estimation and results

We evaluate whether our results are robust regarding the specification of monetary policy. We do this by using the exact same model as in section Section 3.2.3 and simply replacing the Federal Funds rate for the Wu-Xia shadow rate [Wu and Xia, 2016]. The plots of the impulse response functions follow:

Figure 14: Response of GDP growth to oil supply shock (left), aggregate demand shock (middle), oil-specific demand shock (right), using shadow rate
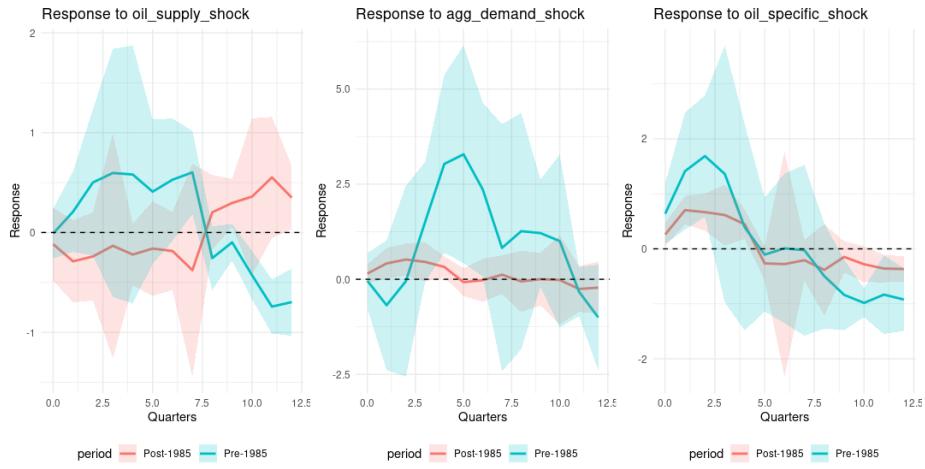

Figure 15: Response of inflation rate to oil supply shock (left), aggregate demand shock (middle), oil-specific demand shock (right), using shadow rate
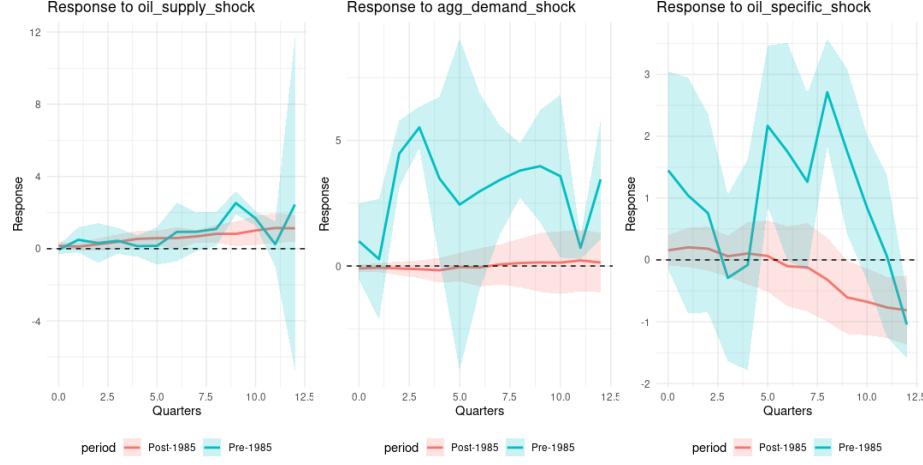
Figure 16: Response of shadow rate to oil supply shock (left), aggregate demand shock (middle), oil-specific demand shock (right), using shadow rate

Again, we see a similar pattern as when we used the federal funds rate to reflect monetary policy: Red confidence bands, belonging to the post-1985 time period, seem to be more closely centered around zero compared to the blue confidence bands, reflecting the pre-1985 time period. These results would indicate that regardless of which of the two measures to reflect monetary policy we use, the data indicates that the relationship between the oil market and US economy has weakened. Again, we use our model with interaction terms to check for significant differences across both period. Table 3 provides a more detailed overview comparing the results of the two analyses using the two different measures reflecting monetairy policy:

Table 3: Significance Comparison Using Federal Funds Rate and Shadow Rate

Variable	Shock	Both Not Sig.	Both Sig.	Only FFR Sig.	Only Shadow Sig.
GDP Growth	Aggregate Demand	8	4	1	0
	Oil-Specific Demand	8	5	0	0
	Oil Supply	12	0	0	1
Inflation	Aggregate Demand	11	0	0	2
	Oil-Specific Demand	2	10	1	0
	Oil Supply	9	0	4	0
Monetary Policy	Aggregate Demand	6	5	2	0
	Oil-Specific Demand	5	7	0	1
	Oil Supply	13	0	0	0

There seems to be one single shock-dependent variable combination where there is a relatively important difference. From the table we can see that four horizons for the effect of an oil supply shock on inflation are significant when using the Federal Funds rate, but are insignificant when using the Wu-Xia shadow

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rate. Since these are the only four significant horizons an oil supply shock has in the estimates using the Federal Funds rate, this means that when using the Wu-Xia, not a single difference between pre-1985 and post-1985 is significant when considering the effect of an oil supply shock. This is in line with what we observed earlier, that it is mainly the relationship between demand shocks and the US economy that has changed, and this also exactly the conclusion of [Kilian, 2009]. Other than this single entry we see that results are robust and there does not seem to be a pattern of more or less significant differences depending on which measure we use to represent the monetary policy of the Federal Reserve. As the large majority of the cases falls in either the "both significant" or the "both not significant" category there is high agreement between the two estimates and the results seem robust to the different model specifications.

4   Limitations and possible extensions

While I believe this study provides valuable evidence that the macroeconomic effects of oil-market shocks on the U.S. economy have changed over time, several limitations should be acknowledged.

Identification of structural shocks: This paper builds on the structural identification proposed in [Kilian, 2009]. While this approach is popular and quite standard in the literature, it should not be free of any scrutiny. The Cholesky identification that is used makes assumptions on the relationship between the dependent variables and how and in which order they influence each other. These assumptions seem quite defensible, but are definitely not the only correct answer. Possible extensions to this paper could be to try different identification strategies such as long-run restrictions or sign restriction and check whether the same conclusions hold.

Asymmetric time-sample: One disadvantage of the local projection method is that the confidence intervals tend to be quite wide. To limit this range one would like to increase the sample period as much as possible. Our analysis already splits the dataset into two parts: pre-1985 and post-1985. Some datasets we used do not reach very far back in to the past. For example the time series we used for the global crude oil production only starts in 1973, after accounting for lags this means that the structural shocks we recreate only start from 1975. Therefore, the pre-1985 period is ten years long while the post-1985 period is around 40 years long. If in the future there would be ways to extend the data availability of the global crude oil production further in the past, one would be able to get even stronger results. Narrower confidence intervals would most likely result in even stronger evidence in favor of the "great moderation theory".

Limited set of macroeconomic variables: Our analysis focuses on GDP growth, inflation, and monetary policy. While these variables capture major macroeconomic channels, oil shocks may also affect other macroeconomic vari-

ables such as labor markets, trade balance or have heterogeneous effects on different industries . Extending the analysis to include variables such as unemployment, import, export or sector-specific indicators could provide valuable insights as well.

5   Conclusions

In this paper, we investigated whether the US economy has become less sensitive to disturbances in the oil market compared to times before 1985. Using Cholesky decomposition following [Kilian, 2009] to obtain structural shocks and using these to perform local projections according to [Jordà, 2005], we found substantial evidence that the relationship has changed indeed. However, similarly to conclusions in [Kilian, 2009] we found that the change is dependent on the type of oil shock. The evidence in this paper indicates that the attenuation of oil shock effects is mainly driven by changes in the transmission of oil demand shocks, while the effect of oil-supply shocks seems to remain relatively stable over time. To take into account the effect of unconventional expansionary monetary policy, which took place in the post-1985 period, we estimated the models employing the Wu-Xia [Wu and Xia, 2016] shadow rate as a substitute for the Federal Funds rate. Table 4 shows how the two analyses match each other.

Table 4: Agreement of significance/non-significance between shadow rate and federal fund rate estimates (%)

Variable	Aggregate Demand Shock	Oil-Specific Demand Shock	Oil Supply Shock
GDP Growth	92.3	100.0	92.3
Inflation	84.6	92.3	69.2
Monetary Policy	84.6	92.3	100.0

The analysis using the shadow rate reaffirms the observation that the type of oil shocks is important, as it shows zero significant changes regarding the effect of oil supply shocks. It demonstrates that it is the relationship with the oil-specific and aggregate demand that has changed rather than the relationship with oil-supply shocks. This pattern is consistent with an economy that has become more resilient to disturbances in the oil market, not because oil has lost its importance altogether, but because structural changes such as improved energy efficiency and improved monetary policy have changed how demand-driven oil price movements affect the economy. Except for this difference, table 4 shows that the two analyses have highly similar results.

In conclusion, while the US economy has become substantially less vulnerable to oil demand shocks due to factors such as improved monetary policy and structural changes in the economy, the US remains exposed to oil supply disruptions. This conclusion has relevant consequences for both energy security policy and energy transition strategies. They suggest that reducing oil depen-

dence remains economically valuable even as improved policy frameworks have mitigated certain oil shock channels.

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