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Information effects of monetary policy announcements on oil price

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ABSTRACT

If the information held by the central bank is different from that of market participants, then the central bank's announcement not only affects the view of monetary policy but also the view of economic fundamentals. This study investigates the information effects of monetary policy announcements on oil prices using a structural vector autoregression (VAR) model identified by sign restrictions. The sign restrictions rely on the high-frequency linkage between stock prices and interest rates surrounding the policy announcements. We find that a positive central bank information shock, which raises the interest rate by six basis points, leads to a 1.7% increase in oil prices within two months. We also find that central bank information shocks affect oil prices through the finance and expectation channels.

1. Introduction

Changes in crude oil prices are generally considered an important factor in understanding fluctuations in economic activity (Barsky and Kilian, 2004; Kilian, 2008; Baumeister and Kilian, 2016; Kilian and Vigfusson, 2017). Therefore, studying various factors that may affect fluctuations in crude oil prices is of great significance to academic economists, investors, and government agencies. The literature documents that fluctuations in crude oil prices are mainly affected by three aspects: global demand (Kilian, 2019), oil supply (Baumeister and Hamilton, 2019), and oil supply news (Känzig, 2021). In addition, some studies have shown that monetary policy significantly impacts oil prices (Glick and Leduc, 2012; Smales, 2019; Apergis et al., 2020).

According to conventional wisdom, tightening monetary policy leads to lower oil prices. However, we find that, in some periods, the response of oil prices to monetary policy is inconsistent with the traditional view. Consider the following example. On January 26, 2022, the Federal Open Market Committee issued a monetary policy announcement, which states that the Committee decided to continue to reduce the monthly pace of its net asset purchases, bringing them to an end in early March. This is a clear monetary tightening. However, after the announcement, WTI oil prices rose from \$86.61 to \$88.33. Therefore, re-examining the impact of monetary policy on oil prices is important for understanding the current economic situation.

To explore the impact of monetary policy on oil prices, many researchers have used the vector autoregression (VAR) model (Bernanke et al., 1997; Anzuini et al., 2013). A standard identifying assumption in VAR models is that oil prices do not respond instantaneously to monetary policy shocks (Kilian and Lewis, 2011; Ratti and Vespignani, 2013; Wen et al., 2019). An obvious concern is that in practice, oil prices may behave like asset prices, responding immediately to any news about monetary policy. Therefore, commonly used empirical models based on the identifying assumption of predetermined oil prices are invalid.

Monetary policy announcements can help overcome the identification challenges in traditional VAR models. The main idea is to measure monetary policy shocks within a tight window surrounding central bank announcements. As no other economic news

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is released regularly, the use of narrow time windows around central bank announcements helps identify monetary policy shocks (Kuttner, 2001; Bernanke and Kuttner, 2005). Kilian and Vega (2011), Chatrath et al. (2012), Rosa (2014), Basistha and Kurov (2015), and Smales (2019) study the effects of monetary policy on oil prices based on evidence from high-frequency monetary announcements. However, when there is information friction, central bank announcements disclose not only pure monetary policy news but also information about the economy (Campbell et al., 2017; Nakamura and Steinsson, 2018; Andrade and Ferroni, 2017 (Cieslak and Schrimpf, 2019; Lakdawala and Schaffer, 2019)). For example, when a monetary policy announcement signals a higher interest rate than markets had been expecting, market participants may update their views on economic fundamentals and become more optimistic about the future, which in turn may raise private-sector consumption and investment. Ignoring the impact of central bank information shocks may bias the inference of monetary policy effects.

Using the identification strategy proposed by Jarociński and Karadi (2020), this study provides empirical evidence of the information effects of central bank announcements on oil prices. The sign restrictions can be summarized as follows: monetary policy shocks cause interest rates to be negatively correlated with stock prices, whereas central bank information shocks cause interest rates to be positively correlated with stock prices. As we measure changes in the interest rate and stock price within a tight window around central bank announcements, these high-frequency changes should only reflect shocks related to monetary announcements. This is a standard assumption in the high-frequency identification literature. (Gürkaynak et al., 2005; Gertler and Karadi, 2015; Miranda-Agrippino and Rey, 2020; Rüth, 2020).

Our estimates imply that monetary policy and central bank information shocks have very different effects on oil prices. Specifically, in response to a tightening monetary policy shock, the oil price has a delayed negative response, reaching a trough of −0.9% five months after the shock. In contrast, oil prices react positively to a positive central bank information shock. Specifically, the increase in oil price reaches a maximum of 1.7% two months after the shock. We also find that the contributions of monetary policy and central bank information shocks to fluctuations in oil prices are not substantial, although not negligible. Monetary policy shocks explain 0.4%–2.5% of fluctuations in the oil price, while central bank information shocks explain 1.6%–2.7% of fluctuations in the oil price. Overall, we may conclude that monetary policy and central bank information shocks help predict oil price movements but are not the main source of fluctuations in the oil price. To some extent, the central bank information shock is an important contributor to historical oil price changes at certain points.

This study contributes to the literature in several ways. (1) To the best of our knowledge, this study is the first to examine the information effects of monetary policy announcements on oil prices. Our results reveal that monetary policy announcements have a strong information effect on oil prices, thereby providing evidence for a new channel through which the central bank can affect oil prices. (2) We find that a positive central bank information shock that raises the interest rate has a positive effect on oil prices. A monetary policy announcement to raise interest rates may reflect an improvement in the prospects for future economic growth and thus have expansionary rather than contractionary effects on oil prices. (3) Although central bank information shocks significantly impact oil price, they are not the main source of fluctuations in oil prices. (4) Our findings confirm that the standard high-frequency identification method that ignores central bank information effects can bias the inference of oil price responses to monetary policy. (5) We find that central bank information shocks affect oil prices through the finance and expectation channels.

The remainder of this paper proceeds as follows. Section 2 reviews the related literature. Section 3 describes the empirical methodology used in this study. Section 4 presents the empirical findings. Section 5 analyzes the transmission channels of monetary policy and the information effect. Finally, Section 6 concludes the paper.

2. Related literature

The relationship between oil prices and monetary policy is widely studied in macroeconomics. A large body of literature focuses on whether monetary policy systematically responds to oil price shocks. In a seminal article, Bernanke et al. (1997) conclude that monetary policymakers respond to a positive oil price shock by raising the interest rate, thereby amplifying the decline in output growth associated with positive oil price shocks. Hamilton and Herrera (2004) argue that Bernanke et al.'s ((1997)) empirical results are driven by model misspecification. Plante (2014) finds that the response of monetary policy to oil price shocks differs significantly, depending on whether oil price changes are driven by demand or supply shocks. Specifically, he shows that the federal funds rate rises (falls) in response to a demand (supply) shock. These empirical results have inspired a series of theoretical studies on how to implement welfare-maximizing monetary policies in response to oil price shocks (Kormilitsina, 2011; Bodenstein et al., 2012; Natal, 2012; Wang et al., 2019).

Causality may run from oil prices to monetary policy, as well as from changes in monetary policy to the price of oil. A large body of empirical literature has used the VAR method to study the impact of monetary policy on oil prices. Kilian and Lewis (2011) use the VAR model to show that monetary tightening in the United States leads to a drop in real oil prices. Anzuini et al. (2013), using a VAR framework, suggest that the expansionary U.S. monetary policy shock significantly increased oil prices. Ratti and Vespignani (2013) find that the cumulative impact of China's money supply on the price of oil is large and statistically significant. Wen et al. (2019) develop a time-varying parameter VAR model to examine the dynamic effects of monetary policy. Their empirical results indicate that China's expansionary monetary policy positively affects crude oil prices. The long tradition in the VAR literature on the effects of monetary policy on oil prices has been to assume that monetary policy shocks do not affect oil prices instantaneously. This assumption is fairly restrictive in reality and may bias the inference of monetary policy effects.

To solve the identification problem in traditional VAR models, a growing body of literature uses information from high-frequency monetary announcements. Kilian and Vega (2011) conduct a comprehensive high-frequency event study analysis and find no evidence that oil prices respond to monetary policy news immediately. Chatrath et al. (2012) extend the study of Kilian and

Vega (2011) to account for inventory changes. In general, their findings support and strengthen the conclusions of Kilian and Vega (2011). Rosa (2014) and Basistha and Kurov (2015) measure monetary policy shocks using changes in interest rate futures prices around monetary announcements rather than from survey forecasts, as in Kilian and Vega (2011) and Chatrath et al. (2012). They find that oil prices respond significantly to monetary shocks. Smales (2019) demonstrates that liquidity is removed from the oil market approximately two minutes before the monetary policy announcement and then reverts to normal within nine minutes of the announcement. A potential shortcoming of these studies is that they ignore the information effects of monetary policy announcements.

The last decade has witnessed an explosion in research on the information effects of monetary policies. Nakamura and Steinsson (2018) find that forecasts of output growth increase in response to an unexpected increase in the interest rate, thereby providing strong support for the Fed information effect. Enders et al. (2019) demonstrate that monetary policy announcements produce an information effect endogenous to the size of policy shocks. Claus and Nguyen (2020) find that policy easing (tightening) is regarded by consumers as a signal of a weakening (strengthening) economy after about 9 to 12 months. Breitenlechner et al. (2021) find that central bank information shocks lead to persistent declines in 10-year government bonds. Gürkaynak et al. (2021) confirm that monetary policy announcements affect exchange rates. Miranda-Agrippino and Ricco (2021) prove that the market-based high-frequency interest rate shocks correlate with central banks' private macroeconomic forecasts, supporting the view that the central bank's private information is disclosed through policy actions. However, no study has investigated the information effects of monetary policy announcements on oil prices. This study addresses this gap in the literature.

3. Empirical methodology

Following Jarociński and Karadi (2020), our empirical analysis is based on the following reduced-form VAR model.

$$\begin{pmatrix} m_t \\ y_t \end{pmatrix} = \sum_{i=1}^{k} \begin{pmatrix} 0 & 0 \\ A^i_{ym} & A^i_{yy} \end{pmatrix} \begin{pmatrix} m_{t-i} \\ y_{t-i} \end{pmatrix} + \begin{pmatrix} 0 \\ \mu_y \end{pmatrix} + e_t, \tag{1}$$

where m_t, y_t, and e_t are $N_m \times 1$, $N_y \times 1$, and $(N_m + N_y) \times 1$ vectors, respectively. e_t is the white-noise reduced-form error with variance–covariance matrix Σ. m_t consists of high-frequency shocks in interest rates and stock prices in a thirty-minute window surrounding policy announcements. The high-frequency shocks of interest rates are measured by the shocks in the three-month fed fund futures. The high-frequency shocks of stock prices are measured by the shocks in the S&P 500 stock market index. y_t consists of monthly macroeconomic and financial variables.

The key issue in the structural VAR model is the decomposition of the reduced-form error e_t into economically meaningful structural shocks. Suppose there are a total of $(N_m + N_y)$ structural shocks, which are mutually independent and normalized to a variance of 1. Therefore, the structural shocks can be written as an $(N_m + N_y) \times 1$ vector u_t with $E(u_t u_t') = I_{(N_m+N_y)}$. To identify structural shocks, we need to find a matrix B, such that $e_t = Bu_t$.

As discussed, we use sign restrictions to identify the structural VAR. Since Faust (1998), Canova and De Nicoló (2002), and Uhlig (2005), sign restrictions have been widely used to identify structural shocks in VAR models. The sign restrictions used in this study can be summarized as follows: monetary policy shocks cause interest rates to be negatively correlated with stock prices, whereas central bank information shocks cause interest rates to be positively correlated with stock prices.[1] To implement the sign identifying restrictions, we apply the method developed by Rubio-Ramírez et al. (2010). The algorithm proceeds as follows.

Step 1. Draw A^i_{ym}, A^i_{yy}, and Σ from the posterior distribution of the reduced-form parameters in VAR (1).

Step 2. Compute the lower-triangular Cholesky decomposition of Σ, which is denoted by C.

Step 3. Let $\tilde{Q}$ be a 2×2 matrix, with each element having an independent standard normal distribution. Let $\tilde{Q} = Q^* R^*$ be the QR decomposition of $\tilde{Q}$ with the diagonal of R^* normalized to be positive. Define $Q = \begin{bmatrix} Q^* & 0 \\ 0 & I_{N_y} \end{bmatrix}$.

Step 4. Let $B = CQ$. Compute the impulse responses using A^i_{ym}, A^i_{yy}, and B. If the impulse responses do not satisfy the sign restrictions, return to Step 3.

Step 5. Given B, the impulse responses, variance decomposition, and historical decomposition can be calculated in the standard way (see, e.g., (Kilian and Lütkepohl, 2017)).

Step 6. Repeat Steps 1–5 multiple times.

According to Baumeister and Hamilton (2015), this traditional sign-restriction algorithm implies informative prior distributions for impulse-response functions that cannot be controlled by the researcher. That is, this algorithm uses more information than is immediately apparent. This means that the results are not driven by the data but mainly by the informative priors inherent in the algorithm. However, this problem is difficult to solve. We earmark this topic for future research.

The literature has documented that global demand shocks are key drivers of oil prices. As central bank information shocks influence the economy primarily by changing individual expectations, we think they may be a particular instance of a global demand shock.

[1] See more details in Table 1 of Jarociński and Karadi (2020).

Table 1
Impact response of announcement surprises to structural shocks.

	Median	68% probability interval	95% probability interval
	Monetary policy shock		
Three-month fed funds futures	0.047	(0.033, 0.055)	(0.024, 0.058)
S&P 500	−0.418	(−0.492, −0.290)	(−0.524, −0.211)
	Central bank information shock		
Three-month fed funds futures	0.030	(0.010, 0.046)	(0.001, 0.051)
S&P 500	0.278	(0.095, 0.412)	(0.014, 0.458)

4. Empirical results

4.1. Model specification

In our empirical model, y_t includes seven variables. (1) U.S. monetary policy indicator measured using the one-year constant-maturity Treasury yield. (2) U.S. real economic activity measured by U.S. real GDP. (3) U.S. price level measured by U.S. GDP deflator.[2] (4) Global crude oil production. (5) Global real economic activity (GECON) measured by Baumeister and Hamilton (2020). (6) Real oil price measured by U.S. refiners' acquisition cost of imported crude oil deflated by the U.S. consumer price index. (7) OECD crude oil inventories obtained from Baumeister and Hamilton (2019). All variables, except Treasury yield, and the GECON index, enter in logs (times 100).

The data are obtained from Jarociński and Karadi (2020), Baumeister and Hamilton (2019), Baumeister et al. (2020), and the U.S. Energy Information Administration. More specifically, high-frequency data (the high-frequency shocks of interest rates and stock prices), one-year constant-maturity Treasury yield, U.S. GDP deflator, and U.S. GDP come from Jarociński and Karadi (2020), which can be obtained from the AEJM website. Global crude oil production and prices are obtained from the U.S. Energy Information Administration (http://www.eia.gov/petroleum/). We choose a monthly measure of global economic conditions (GECON)[3] from Baumeister and Hamilton (2020), which can be obtained from Baumeister's personal homepage. Our dataset contains monthly data from 1984M2 to 2016M12.[4] The reduced-form VAR model (1) uses 12 lags. The model is estimated using the Markov Chain Monte Carlo (MCMC) method. The simulation is based on 4,000 iterations of the Gibbs sampler.[5]

4.2. Impulse response functions

As discussed in Section 3, we use sign restrictions on the impact responses of high-frequency interest rate and stock price shocks to identify monetary policy and central bank information shocks. We define a tightening monetary policy shock as a shock that leads to positive interest rate surprises and negative stock market surprises. In contrast, a positive central bank information shock is defined as a shock leading to positive interest rate surprises and positive stock market surprises. The impact responses of m_t are reported in Table 1. By construction, the impact responses satisfy the sign restrictions described in Section 3.

Fig. 1 shows the impulse response functions (IRFs) of y_t to monetary policy and central bank information shocks. The dotted lines indicate the IRFs for monetary policy shocks. The solid lines, in contrast, report the IRFs to a central bank information shock. Note that we impose no restrictions on the responses of y_t. Fig. 1 shows that our sign restrictions separate the two distinct economic shocks.

Consistent with the standard macroeconomic theory, a tightening monetary policy shock is obviously recessionary. Tight monetary policy depresses real economic activity in the United States and reduces U.S. inflation. The other U.S. variables also respond in line with this theory. The proposed sign restrictions allow for a new investigation of responses to central bank information shocks. In line with Jarociński and Karadi (2020), a positive central bank information shock that increases the U.S. interest rate has an expansionary impact on the U.S. economy. In response to a positive information shock, the U.S. GDP and GDP deflator increase. Central bank information and monetary policy shocks have an intuitive and starkly different impact on the U.S. economy. Therefore, it is important to study the information effect of monetary policy announcements.

In general, the closed economy part of our VAR model aligns well with studies using related methods and confirms the traditional view of the effects of monetary policy tightening. We now consider the spillover effects of U.S. monetary policy. Monetary policy and central bank information shocks move the U.S. interest rate in the same direction but have opposite effects on global real economic activity. Monetary contractions in the U.S. induce a statistically significant decline in global real economic activity, which reaches

[2] Monthly GDP data and monthly GDP deflator data are obtained from Jarociński and Karadi (2020). They apply the method developed by Stock and Watson (2010) to interpolate the quarterly GDP and GDP deflator to the monthly frequency. The main idea is to use the Kalman filter and various monthly variables closely related to economic activity and prices.

[3] The reason why we choose GECON index instead of WIP index is that GECON index performs better for forecasting growth and can better predict the changes in world oil consumption, such as the real price of Brent and global petroleum consumption jointly.

[4] Based on data availability, we use the high-frequency data obtained from Jarociński and Karadi (2020), which is only up to December 2016.

[5] For every draw of As and Σ, we draw a random rotation matrix Q until we obtain a value satisfying the sign restrictions. We sample 6815 times in total and obtain 4000 Q matrices satisfying the sign restrictions.

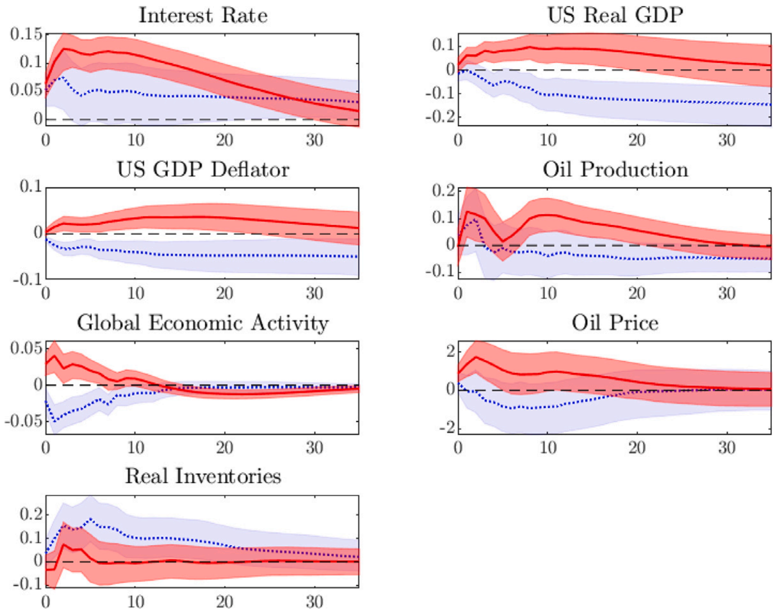

Fig. 1. IRFs to monetary policy and central bank information shocks.
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

a trough after one month. A monetary tightening of the large open economy (the U.S.) would increase the world real interest rate, which would reduce the demand for current goods and services in both the U.S. and non-U.S. countries. This result is theoretically supported by some intertemporal models (e.g., (Svensson and van Wijnbergen, 1989; Obstfeld and Rogoff, 1995)).

In contrast, a positive central bank information shock positively impacts the global real economic activity, which reaches a peak after one month. An unexpected increase in the interest rate around monetary policy announcements likely involves information effects on future economic growth that leads consumers and investors to upgrade their U.S. growth forecasts, which would expand expenditures. Thus, a positive central bank information shock has an expansionary effect on the global economy.

Most notably, monetary policy and central bank information shocks have very different effects on oil price. As shown in Fig. 1, a tightening monetary policy shock reduces oil prices. Specifically, in response to a tightening monetary policy shock, the oil price has a delayed negative response, reaching a trough of −0.9% five months after the shock. In contrast, oil prices react positively to a positive central bank information shock. Specifically, the increase in oil price reaches a maximum of 1.7% two months after the shock.

Both monetary policy and central bank information shocks positively affect oil production and inventory. Positive central bank information shocks make oil manufacturers more optimistic about the future economic situation, thereby increasing oil supply. According to traditional economic theory, a tightening monetary policy shock would encourage oil producers to pump oil in order to invest income at higher interest rates, thereby increasing oil supply.

A lot of literature has documented that the central bank holds private information on economic fundamentals that are distinct from those held by market participants. Therefore, central bank announcements affect beliefs about monetary policy, as well as the state of the economy. A positive central bank information shock reveals good economic news, making market participants more optimistic about future economic growth. Consequently, oil prices increase. The existing literature (see (Barsky and Kilian, 2004; Anzuini et al., 2013; Rosa, 2014); and the references therein) identifies several channels through which the central bank may influence oil prices (i.e., demand, portfolio balance, exchange rate, inventory, and supply channels). Our IRF results reveal that monetary policy announcements have a strong information effect on oil prices, thereby providing evidence of a new channel through which the central bank can affect oil prices.

The oil price response results are consistent with the global real economic activity responses. A tightening monetary policy shock has a contractionary effect on the global economy, which decreases oil prices, while a positive central bank information shock has an expansionary effect on the global economy, which increases oil prices. Thus, monetary policy and central bank information shocks can affect oil prices through the demand channels. Specifically, monetary policy and central bank information shocks affect global economic growth, which, in turn, affects oil demand.

For comparison, Fig. 2 shows the impulse response results based on the standard high-frequency identification (HFI) method. The standard HFI method uses all high-frequency surprises of interest rates as proxies for monetary policy shocks (see more details in (Jarociński and Karadi, 2020)). Fig. 2 shows that the standard HFI method biases the inference of monetary policy shock effects. In particular, the oil price response produced by the standard HFI method is inconsistent with the standard macroeconomic theory.

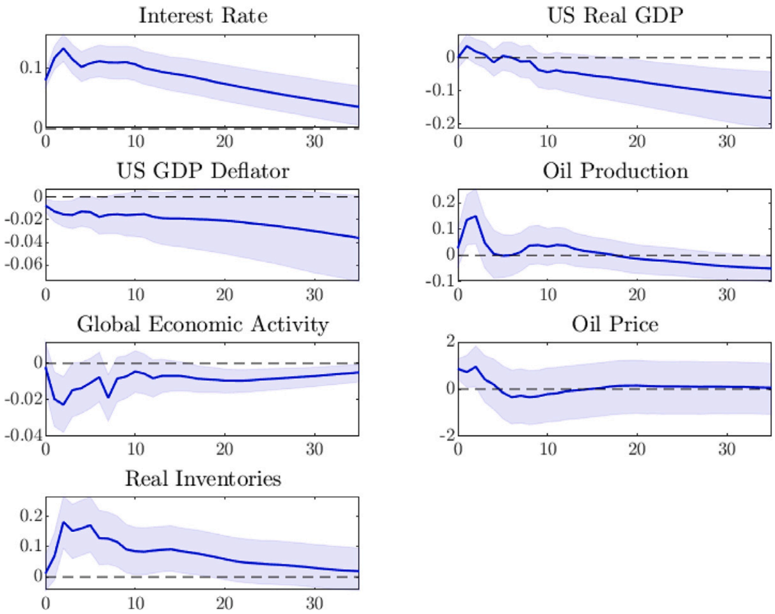

Fig. 2. IRFs to monetary policy shock based on standard HFI method.
Notes: The solid line shows the point-by-point median IRFs to a tightening monetary policy shock and the shaded area shows the associated point-by-point 68% confidence intervals based on standard HFI method.

A tightening monetary policy shock induces an increase in the oil price, and the responses of the oil price are statistically significant for the first two months after the shock. Thus, it is necessary to decompose the news conveyed by central bank announcements into news about monetary policy, as well as central banks' information about economic fundamentals.

4.3. Forecast error variance decomposition

In this section, we investigate the size of the relative contributions of the monetary policy and central bank information shocks to overall oil price fluctuations. This question can be tackled using forecast error variance decomposition (FEVD). The FEVD measures the percentage share of the forecast error variance of a variable due to a specific shock at a specific time horizon. In Fig. 3, we report the FEVD results. In general, the contributions of monetary policy and central bank information shocks to the fluctuations in these variables (except for the U.S. interest rate) are not substantial, although not negligible. Monetary policy shocks explain 0.4%–2.5% of fluctuations in the oil price, while central bank information shocks explain 1.6%–2.7% of fluctuations in the oil price. Overall, we may conclude that monetary policy and central bank information shocks help predict the oil price movements but are not the main source of fluctuations in the oil price. This result is consistent with that of Anzuini et al. (2013). There may be two reasons. The first reason is that crude oil prices are mainly influenced by global demand, oil supply and oil supply news. Central banks have a relatively small role in the oil market. The second reason is that central banks do not have much informational advantage over market participants on oil prices.

4.4. Historical decomposition

Fig. 4 depicts the time path of the monetary policy and central bank information shocks implied by the structural VAR model identified by sign restrictions. Central bank information shocks occur throughout the entire sample period. Note that, during the 2008 financial crisis, there is a series of negative central bank information shocks. During this period, the Federal Reserve lowered the federal funds rate from more than 4% to close to 0% to offset the deterioration in demand caused by the financial crisis. During the financial crisis, we can observe many negative high-frequency interest-rate shocks. Monetary policy statements during the financial crisis have always linked a loose monetary policy stance to slowing economic growth and downside risks. For example, in January 2008, the Federal Reserve announced that "... downside risks to growth remain". In October 2008, the Federal Reserve stated that "Incoming economic data suggest that the pace of economic activity has slowed markedly in recent months". During the 2008 financial crisis, market participants believed that the negative high-frequency interest rate surprises were mostly attributed to the central bank's information effect, which made market participants more pessimistic about future economic growth.

Fig. 5 plots historical decompositions of the oil price based on the structural VAR model. It shows the contributions of the monetary policy and central bank information shocks to the historical movements of the oil price. In general, the monetary policy and central bank information shocks play a small role in the historical behavior of the oil price. This result is consistent with the

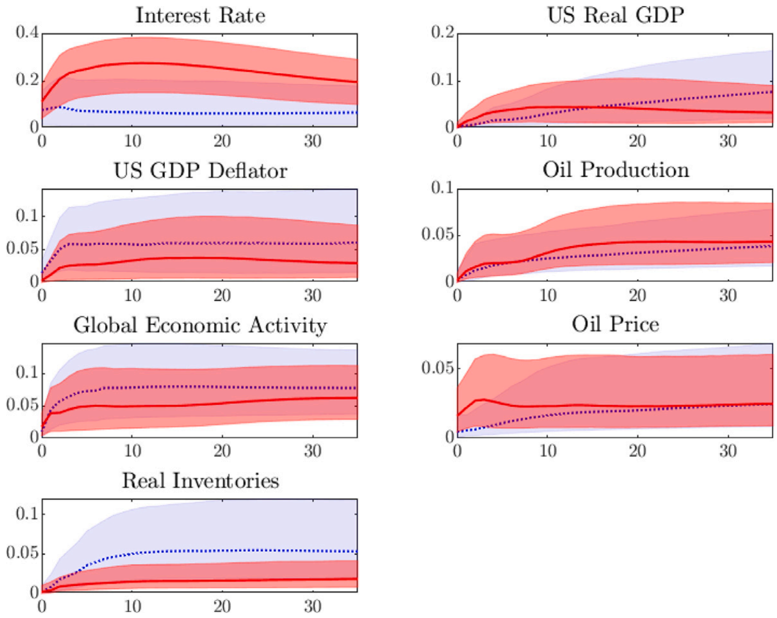

Fig. 3. Fraction of variance explained by monetary policy and central bank information shocks.
Notes: The dotted line shows the point-by-point median FEVD and the light shaded area shows the associated point-by-point 68% confidence intervals for a tightening monetary policy shock. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

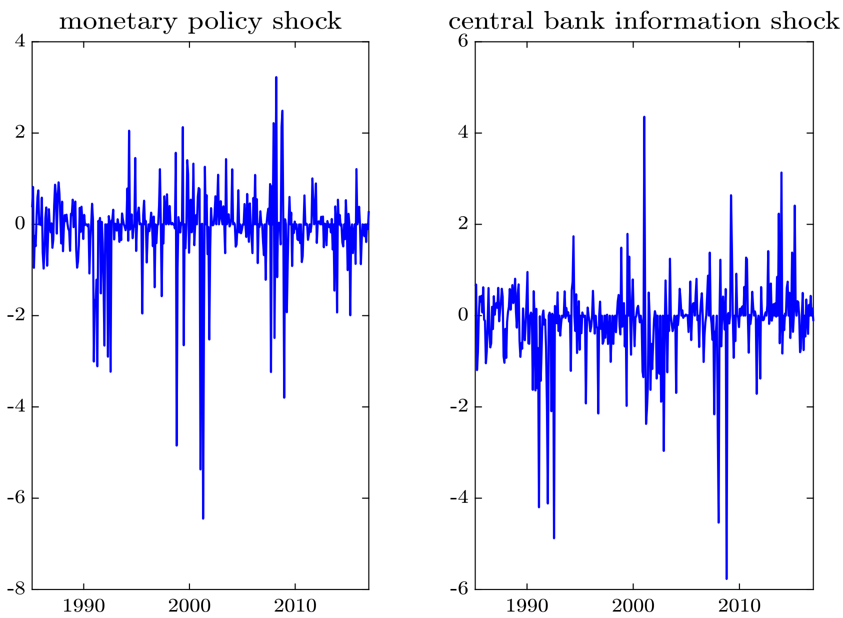

Fig. 4. Historical evolution of the structural shocks.

FEVD result in Fig. 3. However, to some extent, the central bank information shock is an important contributor to the historical oil price change at some particular points.

For a more intuitive sense of the historical effect of oil prices, we focus on a few periods in which central bank information shocks play an important role in oil price fluctuations. Table 2 reports the historical decomposition of oil prices in selected periods. As Table 2 shows, in August 2007, the actual oil price change is −3.58%, whereas the cumulative effect of the central bank information shock on oil prices changes by −2.37%. Information effect shocks account for 66.16% of the price fluctuations. More than half of the oil price changes in August 2007 can be attributed to the central bank information shock. As discussed previously, on January

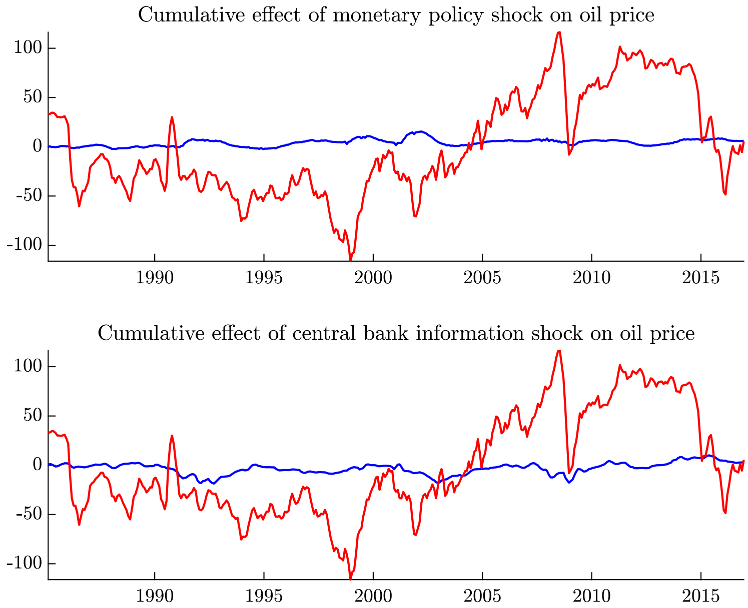

Fig. 5. Historical decomposition of oil price.
Notes: The blue lines are the cumulative effects of the monetary policy shock (or the central bank information shock) on oil prices, while the red lines are the demeaned oil prices. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Historical decomposition of oil prices in selected periods.

Date	$ff4hf$	$oilprice$	$\Delta(oilprice)$	HDI	$\Delta(HDI)$	$\frac{\Delta(HDI)}{\Delta(oilprice)}$
Mar-91	−0.06	256.81	−4.01	−11.72	−1.07	26.73%
Nov-91	−0.12	264.21	−3.04	−11.03	−1.79	58.88%
Dec-91	−0.25	251.96	−12.24	−15.46	−4.43	36.16%
May-94	0.05	236.75	7.73	−2.03	2.20	28.44%
Jul-95	−0.15	238.07	−5.61	−3.52	−1.43	25.44%
Aug-99	0.02	246.01	7.79	−0.56	2.29	29.40%
Jun-02	−0.01	256.93	−4.19	−10.77	−1.45	34.67%
Nov-02	−0.09	256.85	−9.47	−17.29	−2.00	21.13%
Aug-07	−0.03	349.29	−3.58	−2.54	−2.37	66.16%
Apr-09	0.01	314.88	7.48	−6.39	3.90	52.12%
Aug-11	−0.01	377.93	−7.09	0.88	−1.57	22.18%
Mar-13	0.01	375.34	0.61	0.13	0.08	52.22%
Sep-15	−0.06	285.15	−4.78	7.01	−1.32	27.54%

Notes: $ff4hf$ denotes the high-frequency changes of three-month fed funds futures, HDI denotes the cumulative effect of the central bank information shock on oil prices, and Δ denotes first-order difference.

26, 2022, WTI oil prices rose in response to a monetary tightening. This may caused by the central bank information shocks. Thus, this study helps to understand the current economic situation.

4.5. Robustness analysis

In this section, we report various robustness checks. Due to space limitations, we only present the results of the responses of the U.S. interest rate and oil price.

The first robustness check involves alternative measures of oil prices. We replace the U.S. refiners' acquisition cost of imported crude oil in the baseline model with the WTI oil price. WTI stands for West Texas Intermediate, an oil benchmark central to commodity trading. The response results are shown in Fig. 6. The main results are maintained, with minor differences in the response estimates.

The second robustness check involves alternative measures of high-frequency interest rate and stock price shocks. The "policy indicator" constructed in Gürkaynak et al. (2005) is calculated as an alternative measure of the interest rate surprises. More specifically, we calculate the first principal component of high-frequency surprises in the current month and three-month fed funds futures and two, three, and four quarters ahead of three-month Eurodollar futures. To construct an alternative measure of high-frequency stock price surprises, we calculate the first principal component of high-frequency shocks in the S&P 500, Nasdaq

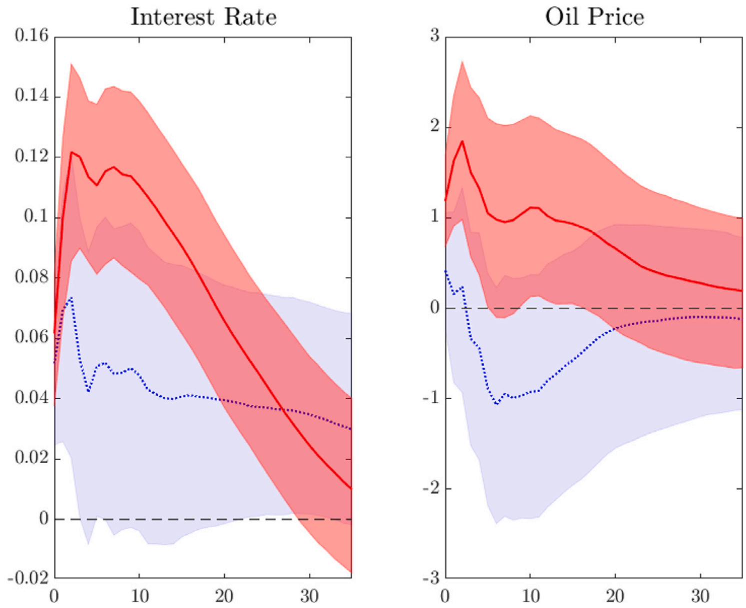

Fig. 6. IRFs to monetary policy and central bank information shocks (VAR with WTI oil price).
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock, and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

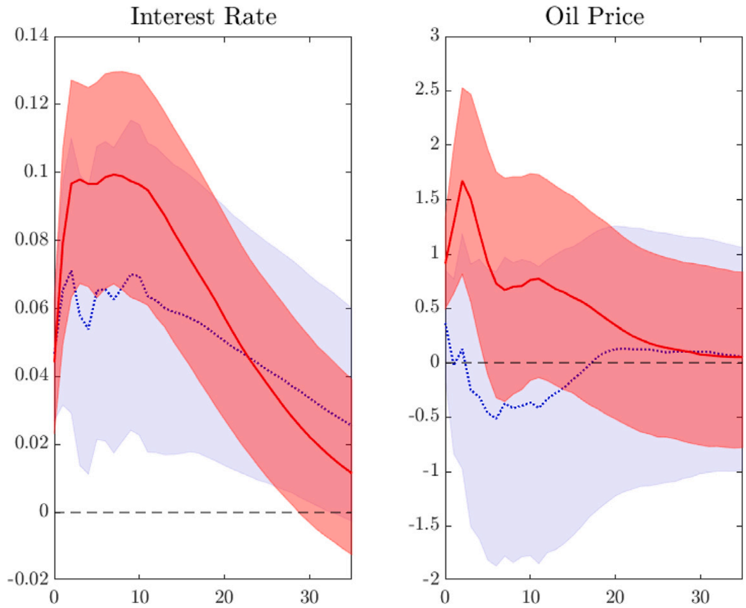

Fig. 7. IRFs to monetary policy and central bank information shocks (VAR with factors of surprises).
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock, and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

Composite, and Wilshire 5000. The Nasdaq Composite covers more than 3,000 stocks, all of which are listed on the NASDAQ Stock Market. The Wilshire 5000 is the broadest stock market index for publicly traded American corporations. It is often used as a benchmark for the entire U.S. stock market and is widely regarded as the best single measure of the overall U.S. stock market. We use the factors extracted from multiple interest rates and stock market high-frequency surprises as m_t in the VAR model (1). The response results are shown in Fig. 7. The overall differences are small and mostly contained within the credible sets of the benchmark model.

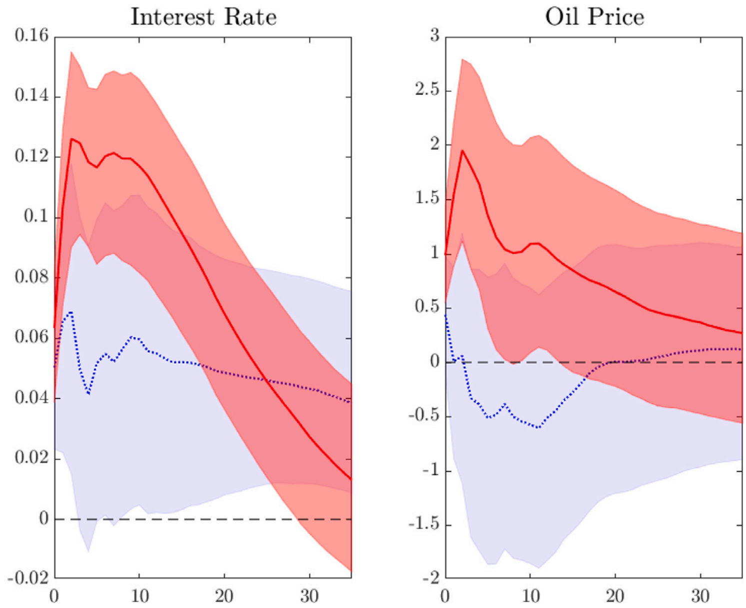

Fig. 8. IRFs to monetary policy and central bank information shocks (Global Real Economic Activity).
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock, and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

The third robustness check replaces global economic activity (GECON) with the Global Real Economic Activity from Kilian (2019). As Fig. 8 shows, these conclusions remain robust.

The final robustness check involves the method of reporting the IRF. Baumeister and Hamilton (2020) show that reporting summary statistics such as the median and 68% posterior density interval is incorrect because there is no basis in the data for choosing one point in the identified set over any other. Therefore, we consider an alternative method for reporting the IRF.

We apply the method proposed by Baumeister and Hamilton (2020), which reports the upper and lower bounds of the full set of all retained draws.[6] As shown in Figs. 9 and 10, similar to Baumeister and Hamilton (2020), the identified set is very wide, making it difficult to draw meaningful economic conclusions.

5. Transmission channel

In this section, we explore the potential transmission channels of monetary policy and information shocks. Based on the previous literature, we consider four channels: inventory, supply, finance and expectation. In theory, monetary policy shocks can affect oil prices through the inventory, supply, finance and expectation channels, while central bank information shocks can affect oil prices through the finance and expectation channels. We conjecture that the central bank information shock can affect oil supply and inventory through expectation channel, but cannot affect oil supply and inventory directly.

First, we consider the inventory channel. According to classical economic theory, raising the interest rate increases the opportunity cost of carrying inventory, reduces the demand for oil inventory, and leads to a decline in oil prices. As shown in Fig. 1, tightening monetary policy shocks increases oil inventories, which is inconsistent with the standard theory.

Second, we consider the supply channel. According to classical economic theory, monetary tightening encourages oil producers to pump oil in order to invest income at higher interest rates. Therefore, from a supply perspective, increasing interest rates will increase oil production and reduce oil prices. As shown in Fig. 1, tightening monetary policy shocks immediately lead to an increase in oil production, which is consistent with our analysis.

Third, we consider the finance channel. According to classical economic theory, tightening monetary policy increases the opportunity cost of holding speculative positions in the oil futures market, thereby causing oil prices to fall. On the contrary, positive information shocks imply that investors will have stronger incentives to chase risky assets (such as oil) in search of higher returns, thereby causing oil prices to rise. We use the oil non-commercial net long position[7] to assess the importance of this channel (See Anzuini et al. (2013) for more details). As shown in Fig. 11, the positive central bank information shock (tightening monetary policy shock) leads to an increase (a decrease) in oil non-commercial net long position, which is consistent with the theory.

[6] We sample 6815 times in total and obtain 4000 Q matrices satisfying the sign restrictions.

[7] Based on data availability, we use the monthly oil non-commercial net long position data from 1995M1 to 2016M12, which can be obtained from the U.S. Commodity Futures Trading Commission.

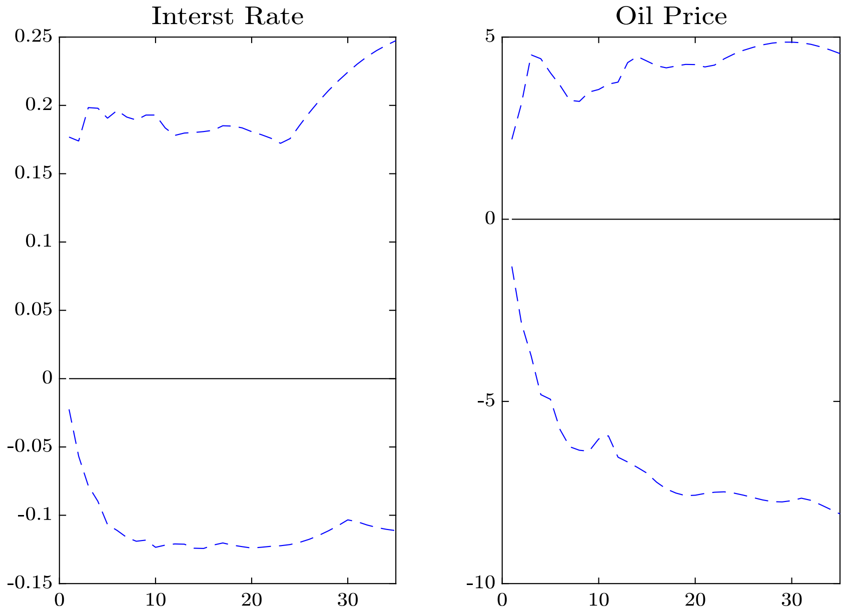

Fig. 9. The responses of the oil price to monetary policy shocks (reporting the upper and lower bounds of the full set of all retained draws).
Notes: The upper and lower bounds of the full identified sets for structural impulse-response functions.

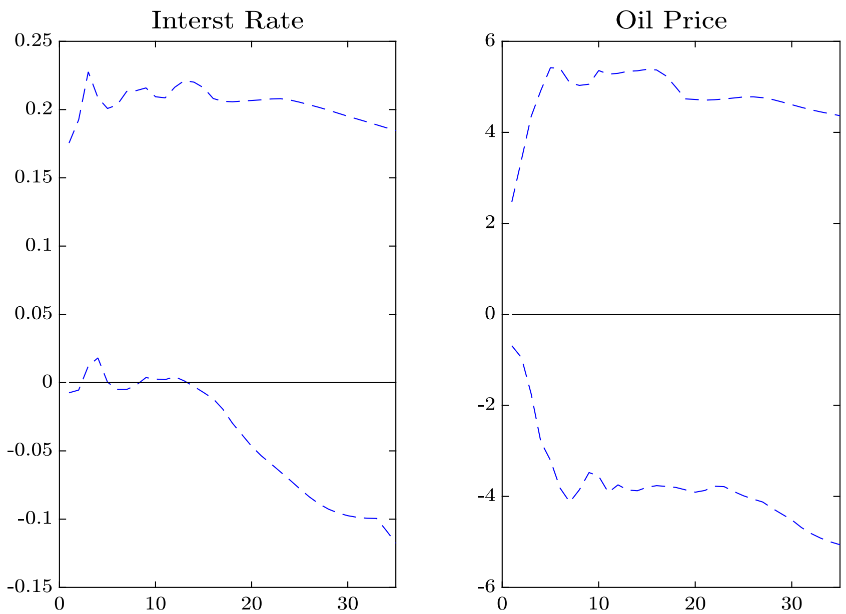

Fig. 10. The responses of the oil price to the central bank information shocks (reporting the upper and lower bounds of the full set of all retained draws).
Notes: The upper and lower bounds of the full identified sets for structural impulse-response functions.

Finally, we consider the expectation channel. According to economic theory, tightening monetary policy shocks cause some market participants to have negative expectations for the economic outlook, which reduces oil prices. In contrast, positive central bank information shocks make some market participants more optimistic about the economic outlook, which increases oil prices. We consider two expectation variables that reflect individual expectations from different perspectives. To compute the IRFs, we augment the baseline VAR model by one variable at a time.

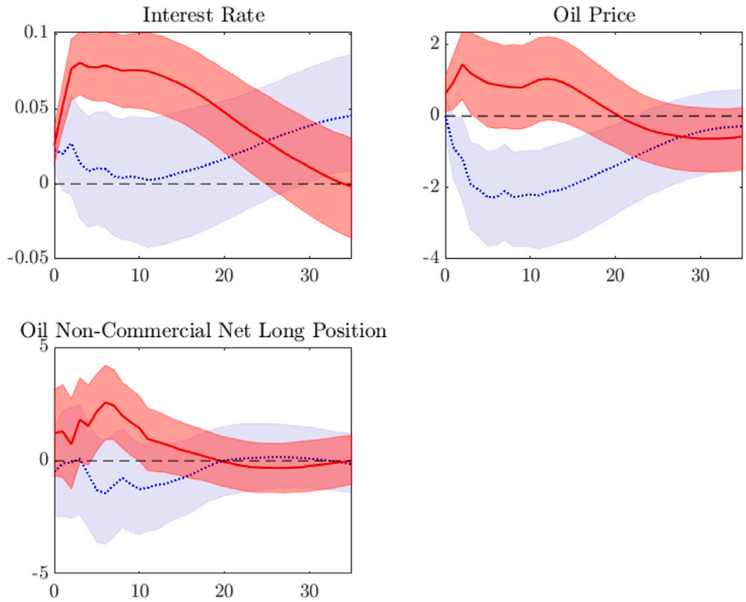

Fig. 11. The responses of the oil price to monetary policy and central bank information shocks (adding oil non-commercial net long position).
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock, and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

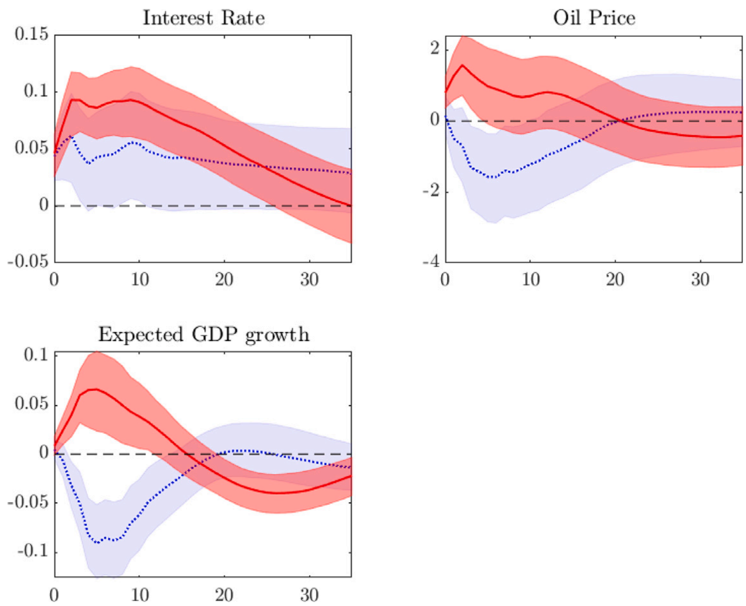

Fig. 12. The responses of the oil price to monetary policy and central bank information shocks (adding GDP expectation).
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock, and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

The first expectation variable we consider is GDP expectation,[8] which can be obtained from Jarociński and Karadi (2020). The unexpected increase in the interest rate can make some market participants more optimistic about future economic growth, thereby boosting the economy. As shown in Fig. 12, the empirical results prove that GDP expectation is one of the channels through which central bank information and monetary policy shocks can affect oil prices.

[8] Because we cannot obtain world GDP and CPI expectation data, we use U.S. GDP and CPI expectation data instead.

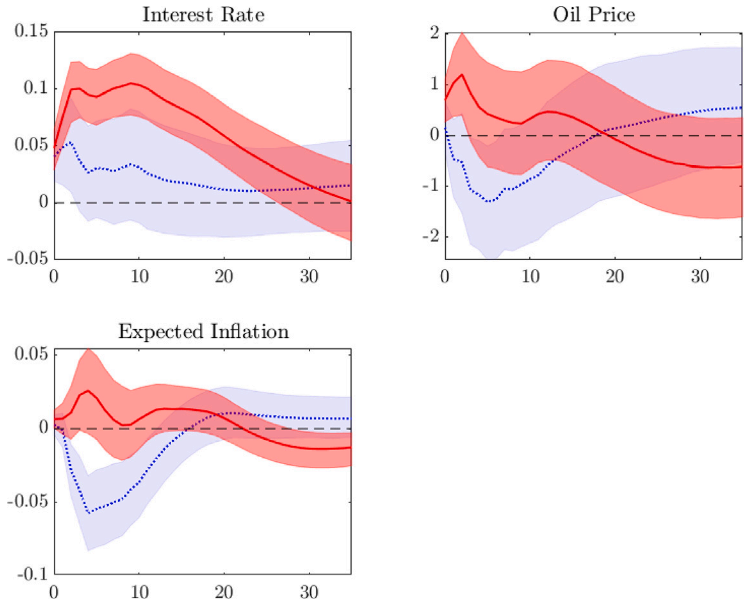

Fig. 13. The responses of the oil price to monetary policy and central bank information shocks (adding CPI expectation).
Notes: The dotted line shows the point-by-point median IRFs to a tightening monetary policy shock, and the light shaded area shows the associated point-by-point 68% confidence intervals. The solid line and darker shaded areas show the equivalent quantities for a positive central bank information shock.

The second expectation variable considered is the CPI expectation. As shown in Fig. 13, the response of the CPI expectation is consistent with economic theory, indicating that CPI expectation plays a role in the transmission of monetary policy and central bank information shocks.

In summary, monetary policy shocks affect oil prices through the supply, finance and expectation channels, while central bank information shocks affect oil prices through the finance and expectation channels.

6. Conclusion

The central bank's announcement not only affects the perception of monetary policy but also the perception of economic fundamentals. Using a structural VAR model identified by sign restrictions, this study investigates the information effects of monetary policy announcements on oil prices. We find that a positive central bank information shock that raises the interest rate positively affects oil prices. A monetary policy announcement that raises interest rates might reflect an improved outlook on future economic growth and thus have expansionary rather than contractionary effects on oil prices. Our results reveal that monetary policy announcements have a strong information effect on oil prices, thereby providing evidence for a new channel through which the central bank can affect oil prices.

Although central bank information shocks significantly impact oil prices, they are not the main source of fluctuations in oil prices according to the FEVD results. Our findings confirm that the standard HFI method, which ignores central bank information effects, can bias the inference of oil price responses to monetary policy. We conduct various robustness checks, which confirm that the main results are robust. Finally, we find that central bank information shocks affect oil prices through the finance and expectation channels.

CRediT authorship contribution statement

Yang Yang: Conceptualization, Methodology, Software, Writing. **Jiqiang Zhang:** Data curation, Writing – review & editing, Software. **Sanpan Chen:** Validation, Writing – review & editing, Software.

Declaration of competing interest

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

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Appendix

(1) A simple conceptual framework

Jarociński and Karadi (2020) recorded a noteworthy stylized fact that stock prices often react wrongly to interest rate shocks, that is, stock prices rise in response to an interest rate hike. To explain this counterintuitive positive relationship, we propose a simple conceptual framework, that motivates the identification strategies used in our empirical analysis. According to standard asset pricing models, the stock price S_t depends on the discount rate r_t and expected future cash flows C_t. The monetary policy shock m_t and the central bank information shocks i_t affect both r_t and C_t.

The total derivative of S_t to m_t is given as follows:

$$\frac{\partial S_t}{\partial m_t} = \frac{\partial S_t}{\partial r_t}\frac{\partial r_t}{\partial m_t} + \frac{\partial S_t}{\partial C_t}\frac{\partial C_t}{\partial m_t}. \tag{2}$$

Using the standard asset pricing theory, we have $\frac{\partial S_t}{\partial r_t} < 0$ and $\frac{\partial S_t}{\partial C_t} > 0$. A tightening monetary policy shock induces an increase in the interest rate, which is likely associated with an increase in the discount rate r_t and an economic slowdown. The economic slowdown reduces future cash flows C_t. Therefore, we have $\frac{\partial r_t}{\partial m_t} > 0$ and $\frac{\partial C_t}{\partial m_t} < 0$. This means that the response of stock prices to a tightening monetary policy shock is the sum of two negative components. Thus, a monetary policy shock induces a negative relationship between interest rates and stock prices.

The total derivative of S_t to i_t is given as follows:

$$\frac{\partial S_t}{\partial i_t} = \frac{\partial S_t}{\partial r_t}\frac{\partial r_t}{\partial i_t} + \frac{\partial S_t}{\partial C_t}\frac{\partial C_t}{\partial i_t}. \tag{3}$$

According to Jarociński and Karadi (2020), a positive central bank information shock induces an increase in interest rate, which is likely related to an increase in r_t. Therefore, we have $\frac{\partial r_t}{\partial i_t} > 0$. Romer and Romer (2000) and Faust and Wright (2009) prove that central banks generally have an information advantage over private-sector market participants. Monetary policy announcements related to interest rate hikes may cause market participants to adopt a more optimistic attitude towards the economic outlook. This can have an expansionary effect on the economy, which is related to an increase in C_t. Therefore, we have $\frac{\partial C_t}{\partial i_t} > 0$. Empirical estimates of various specifications of the Taylor rule imply that the interest rate will not be adjusted one-to-one according to growth expectations (Clarida et al., 2000; Smets and Wouters, 2007; Coibion and Gorodnichenko, 2011; Arias et al., 2019). Thus, it is plausible that the last term dominates in Eq. (3). The overall sign of the derivative of the stock price to the central bank information shock is likely to be positive. Thus, a central bank information shock creates a positive relationship between interest rates and stock prices.

(2) The prior

The VAR in (1) in matrix notation is

$$\begin{pmatrix} M & Y \end{pmatrix} = X \begin{pmatrix} 0 & A \end{pmatrix} + \begin{pmatrix} E^m & E^y \end{pmatrix}. \tag{4}$$

where $M = (m_1, m_2, \ldots, m_T)'$, $Y = (y_1, y_2, \ldots, y_T)'$, X is a matrix that collects the right-hand-side variables, with a typical row $x_t' = (m_{t-1}' y_{t-1}', \ldots, m_{t-k}' y_{t-k}' 1)$, $A = (A_{YM}^1, A_{YY}^1, \ldots, A_{YM}^k, A_{YY}^k, \mu_y)'$, $E^m = (\varepsilon_1^m, \ldots, \varepsilon_T^m)'$ and $E^y = (\varepsilon_1^y, \ldots, \varepsilon_T^y)'$, $e_t = (E^m E^y)'$.

The prior for A and Σ is independent normal-inverted Wishart,

$$p(A, \Sigma) = p(A)\, p(\Sigma), \tag{5}$$

where

$$p(\Sigma | \underline{S}, \underline{v}) = IW(\underline{S}, \underline{v}) \propto |\Sigma|^{-\underline{v}/2} \exp\left(-\tfrac{1}{2} tr \underline{S} \Sigma^{-1}\right), \tag{6}$$

$$p(vec A | \underline{A}, \underline{Q}) = N(vec \underline{A}, \underline{Q}) \propto \exp\left(-\tfrac{1}{2} vec(A - \underline{A})' \underline{Q}^{-1} vec(A - \underline{A})\right), \tag{7}$$

IW denotes the Inverted Wishart distribution and N denotes the normal distribution. See the online appendix of Jarociński and Karadi (2020) for further details.

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