Abnormal crude oil price movements prior to FOMC announcements

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Abstract

We investigate crude oil price movements that are affected by monetary policy rate expectations prior to the Federal Open Market Committee (FOMC) announcements. This study finds that the oil market has experienced huge price drops before scheduled FOMC announcements, which decide to cut the U.S. monetary policy rate. The oil price drops about 1 percent on average, and it is affected by expected monetary policy rate changes but not by unexpected changes. We also find that a positive expectation regarding the policy rate decision has an asymmetric effect, which attenuates oil price movements in the pre-FOMC dates. Our results show that changes in expectations to monetary policy rate decision in the following FOMC meeting are already reflected in the oil price prior to the next FOMC announcement and that the abnormal oil price movements in the pre-FOMC periods still exist after controlling for changes in expectations though. Finally, we find that the conditional volatility of oil price increases in the pre-FOMC dates, only if the expected policy rate change is negative, which can be explained by the volatility feedback effect.

Keywords: Monetary policy, Federal funds rate, Crude oil price

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1. Introduction

Monetary policy and oil price are important components for every country to maintain and improve their national economies. In particular, monetary policy of the U.S. greatly influences the global economy compared with the monetary policy of any other country. Lucca & Moench (2015) find that the S&P 500 Index and the indices in other major countries experience a positive drift before a Federal Open Market Committee (FOMC) announcement, even though the announcements by other central banks do not create a significant drift in their countries' market indices (Brusa et al., 2016). Numerous researchers have investigated the relationship between U.S. monetary policy and crude oil prices: however, there has been no straightforward result. Theoretically, the monetary policy rate negatively affects oil price through several channels (Barsky & Kilian, 2004 and Frankel, 2006). However, many studies argue that there is no empirical evidence supporting the negative effect of the policy rate on oil price (Frankel, 2006, Kilian & Vega, 2011, Basistha & Kurov, 2015, and others).

Without considering the exact relationship between the monetary policy rate decision and oil price, we find that the oil market has undergone huge price drops before scheduled FOMC announcements when the Committee decides to cut its policy rate. The oil price has dropped about 1 percent on average on the day prior to the FOMC announcement since 1985, but we find no evidence of any price drops prior to 1994. This is related to the fact that the FOMC started to announce the outcome of their discussions and policy rate decisions after February 1994. Before then, in most cases, market participants would perceive the monetary policy rate change a few days after the FOMC's decisions. Bernanke & Kuttner (2005) and Lucca & Moench (2015) provide a detailed description of the FOMC announcement policy before and after 1994. For this reason, market participants before February 1994 may have different perspectives regarding

FOMC's policy rate decisions and their timings: therefore, we cannot determine any price drops that occurred on the day before the FOMC's policy rate cuts.

In this study, we try to figure out what drives these highly significant price drops on the day before a policy rate cut. The first thing we need to consider is the information leakage based explanation. This suggests that oil market participants have greater insight or more accurate information about the policy rate decision at the next day's FOMC meeting. A policy surprise measure introduced by Kuttner (2001) can gauge the market's unexpected portion of the target rate change and the information leakage explanation can be tested using this policy surprise measure. However, the estimation results show that the oil price drop is not driven by unexpected policy rate change. Interestingly, the anticipated portion of the policy rate change is strongly related to this phenomenon, even though a positive expected policy rate has an asymmetric effect on the oil price. This interesting result leads to another research question: whether the positive expectation of monetary policy rate does not affect oil price.

We develop two possible explanations. First, a policy rate increase may not affect oil price. Second, expectations of monetary policy rate rise may already be reflected in the oil price prior to the pre-FOMC dates because expectations of the Federal Reserve's target rate decision at scheduled FOMC meetings exist at any time. By using the daily expectation change of future policy rate decision measures, we find some evidence that supports our second explanation. Our results show that a 100 basis points rise in the expectation of future FOMC rate decisions is associated with an approximate 2.7 percent increase in crude oil price and the effects are symmetric for both positive and negative changes in policy rate expectations. Finally, we examine conditional volatility movements during the pre-FOMC periods using a GARCH(1,1) model. Our results show that conditional volatility increases in the pre-FOMC announcements only if the expectation of the policy rate change is negative, which may be evidence of a volatility feedback effect.

The rest of the paper is organized as follows. Section 2 provides a summary of the abnormal crude oil price movements in the pre-FOMC announcements and Section 3 describes the data. Section 4 presents empirical results and Section 5 concludes.

2. Oil price movements around FOMC announcements

Figure 1 illustrates the average of the cumulative returns of oil futures price. This figure comprises 1-month West Texas Intermediate (WTI) crude oil futures price return data from January 1985 to February 2016. At time 0, the FOMC announces its policy rate decision at its scheduled meetings, and we accumulate the log returns of the futures prices in terms of their direction beginning five days before the scheduled FOMC announcements. The black dotted line shows the average of cumulative returns before and after a policy rate rise, the gray solid line illustrates the average of cumulative returns before and after the FOMC's federal fund rate cut decisions, and the gray dotted line indicates average returns around the FOMC's hold decisions. Finally, the black solid line represents all of the returns around the FOMC announcement dates. Several interesting points can be noted from this figure. First, oil futures prices move according to the FOMC's decisions. When the policy rate is increased, the oil price tends to rise and vice versa. Second, the most interesting observation is that the oil price reacts before the scheduled FOMC announcements are released. In Figure 1, the FOMC Decrease and FOMC Increase components start to change directions before time 0, which is the scheduled FOMC announcement date. In the next section, we discuss this phenomenon.

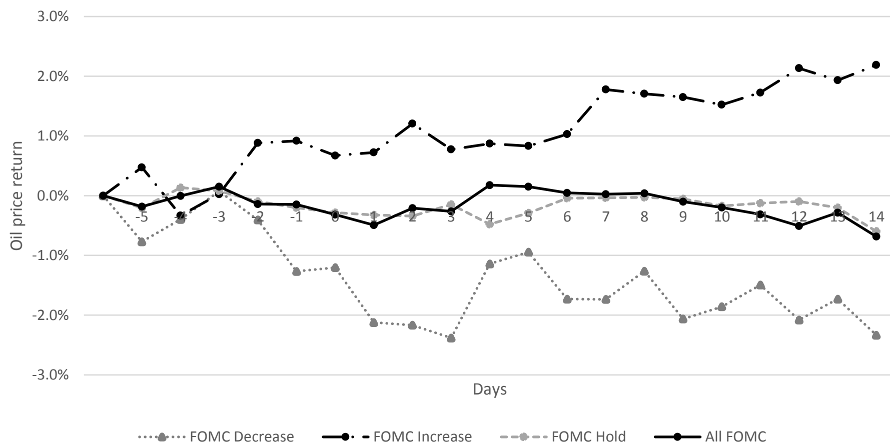

Fig 1. Cumulative returns of oil prices around the scheduled FOMC announcements. This figure shows the cumulative returns of oil futures around the scheduled FOMC announcements between January 1985 and February 2016.

3. Data

Our samples include data from January 1985 to February 2016. The samples also include 246 scheduled FOMC meetings and 7774 trading days. The historical scheduled FOMC meeting dates are obtained from the Board of Governors of the Federal Reserve System database. We use the West Texas Intermediate (WTI) crude oil futures traded on the New York Mercantile Exchange (NYMEX) as the crude oil price. The nearest WTI futures contracts are used and replaced by the next month contracts in the last three trading days because the nearest futures contracts lose their liquidity on their last trading day. Additionally, we examine the robustness using WTI crude oil spot price, and the results are almost the same as the results from our analysis using crude oil futures price. To construct the measures that capture changes in monetary policy expectations, we use federal funds futures data. The federal funds futures rate, 100 minus its price represents the market's expectation of the daily average federal funds effective rate in the contract month. Kuttner (2001) constructs the unexpected policy rate change by using the difference in the federal funds

Table 1
Summary statistics.
The table reports the summary statistics of the main variables of this research. Crude oil is the log return of the WTI crude oil futures prices from January 1985 to February 2016. Crude oil (after 1994) includes oil price returns after February 1994. Policy rate change is the monetary policy rate change following the scheduled FOMC announcements. Unexpected rate change measures the surprise component of the monetary policy rate change, and expected rate change is the anticipated portion of the monetary policy rate change on the pre-FOMC announcement dates.

Variable	Mean	Std.Dev.	Max	Min	Obs.
Crude oil	0.004	2.405	15.552	−40.048	7774
Crude oil (after 1994)	0.016	2.293	15.522	−17.015	5492
Policy rate change	0.003	0.204	0.750	−0.750	174
Unexpected rate change	−0.004	0.047	0.167	−0.194	174
Expected rate change	0.007	0.191	0.610	−0.917	174

futures rate. It captures the surprise component of monetary policy rate decisions on the FOMC meeting dates. To capture the daily expectation change, we construct the change in the market's expectation of the monetary policy rate decision on future FOMC meeting by extending the unexpected rate change on the FOMC meeting dates. Macroeconomic news surprises are used as the control variables, which are constructed using macroeconomic announcements and their expectations (Balduzzi et al., 2001 and Andersen et al., 2003). Table 1 reports the summary statistics of the data and their correlations.

4. Empirical results

In this section, we focus on the relationship between oil prices and the scheduled FOMC meetings, especially the U.S. policy rate decisions from January 1985 to February 2016. We first show that there are significantly negative price movements prior to policy rate cut decisions at the scheduled FOMC meetings. Then, we document that these effects are related to the policy rate change and the expected policy rate change on the scheduled FOMC dates. Lastly, we investigate the relationship between conditional volatility on the pre-FOMC announcement dates and market expectation of policy rate change.

4.1. Oil price drop before a policy rate cut

To verify this phenomenon, which occurs prior to FOMC announcements, we run a regression containing dummy variables,

$$\begin{aligned} r_t = \beta_0 &+ \beta_1 * \textit{Pre FOMC Increase Dummy}_t \\ &+ \beta_2 * \textit{Pre FOMC Decrease Dummy}_t \\ &+ \beta_3 * \textit{Pre FOMC Holding Dummy}_t + \epsilon_t \end{aligned} \tag{1}$$

where r_t denotes the log return on oil futures prices: *Pre FOMC Increase(Decrease) Dummy*$_t$ is equal to 1 if there is a FOMC decision that increases (decreases) the federal funds rate after the scheduled FOMC meeting on day $t+1$, otherwise it is 0 and *Pre FOMC Holding Dummy*$_t$ is equal to 1 when the FOMC decides to maintain its federal funds rate at the existing level on day $t+1$, otherwise it is 0.

Table 2 shows the regression coefficients and their robust standard errors (White, 1980). In this table, β_2 has a negative and significant coefficient, -0.992, which means that the day before the FOMC announces a policy when it decides to cut the policy rate, the oil price has already moved downwards. However, we do not find such movements when the FOMC raises its policy rate or decides to maintain its current policy. As already mentioned, the Federal Reserve started to announce its policy of target rate changes immediately after the FOMC meetings post February 1994. In the pre-1994 period, the policy rate was changed frequently, and these changes often became known a few days after the FOMC meetings. We plot the cumulative return of oil futures around the FOMC's policy rate cut decision using the pre-February 1994 samples. They clearly show that there were no such price movements in the period before February 1994.

In Table 3, we run regressions for different subsample periods. Similar to the intuition from Figure 2, the results in column (2) also show that there is no

Table 2
Different responses of crude oil price to the next day's policy rate decisions.
This table contains results from the following regression:
$r_t = \beta_0 + \beta_1 * \textit{Pre FOMC Increase Dummy}_t + \beta_2 * \textit{Pre FOMC Decrease Dummy}_t$
$+ \beta_3 * \textit{Pre FOMC Holding Dummy}_t$,
where r_t denotes the log return on the oil futures prices: *Pre FOMC Increase(Decrease) Dummy*$_t$ is equal to 1 if there is an FOMC decision that increases (decreases) the Fed rate after the scheduled FOMC meeting on day $t+1$, otherwise it is 0 and *Pre FOMC Holding Dummy*$_t$ is equal to 1 when the FOMC decides to maintain their Fed rate at the existing level on day $t+1$, otherwise it is 0. *Pre FOMC Dummy*$_t$ is equal to 1 if there is an FOMC announcement on day $t+1$, otherwise it is 0. All specifications are derived from ordinary least squares (OLS) using a Huber-White heteroskedasticity consistent covariance matrix. Robust standard errors are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Crude oil (WTI)	
Constant	0.005 (0.026)	0.005 (0.026)
Pre FOMC Increase Dummy	0.410 (0.972)	-
Pre FOMC Decrease Dummy	-0.992^{***} (0.366)	-
Pre FOMC Holding Dummy	0.044 (0.185)	-
Pre FOMC Dummy	-	-0.054 (0.155)

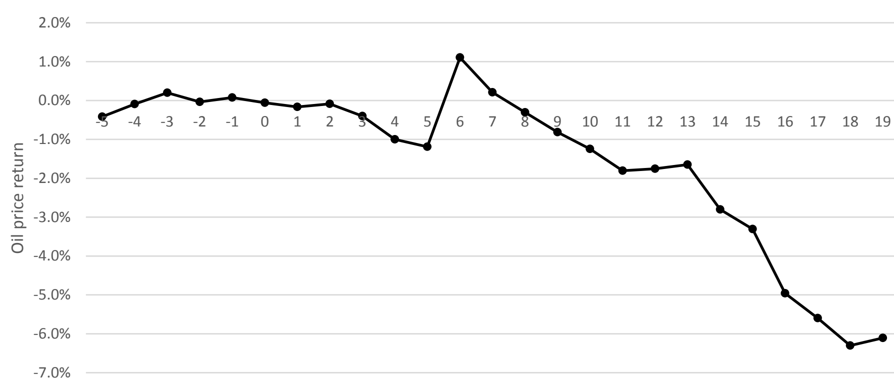

Fig 2. Cumulative oil price return around a policy rate cut at scheduled FOMC meetings before 1994.
This figure shows the cumulative return of oil futures around the scheduled FOMC meetings when the Committee decreased the monetary policy rate in the period between January 1985 and January 1994.

Table 3
Oil price movements around U.S. monetary policy rate cuts.
This table contains results from the following regression:
$r_t = \beta_0 + \beta_1 * \textit{Pre FOMC Decrease Dummy}_{t-i} + \epsilon_t$,
where r_t is the oil futures price return and $\textit{FOMC Decrease Dummy}_{t-i}$ is equal to 1 if there is an FOMC decision that decreases the monetary policy rate after the scheduled FOMC meeting on day $t - i$, otherwise it is 0. Column (1) includes the whole sample, from January 1985 to February 2016, column (2) includes the sample from January 1985 to January 1994, and column (3) includes the sample from February 1994 to February 2016. All specifications are derived from OLS using Huber-White heteroskedasticity consistent covariance matrix. Robust standard errors are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Date around FOMC Decrease	(1)	(2)	(3)
+2	0.143	−0.311	0.679
	(0.386)	(0.354)	(0.531)
+1	0.020	0.212	−0.332
	(0.377)	(0.581)	(0.524)
FOMC Decrease	−0.006	−0.546	0.326
	(0.025)	(0.565)	(0.565)
−1 (*Pre FOMC Decrease*)	−0.995***	−0.518	−1.282***
	(0.366)	(0.67)	(0.415)
−2	−0.785**	−0.881	−0.723*
	(0.373)	(0.68)	(0.433)
−3	0.655	0.767	0.591
	(0.429)	(0.476)	(0.625)
No. of Obs.	7774	2282	5492
No. of FOMC	246	72	174

significant effect of the FOMC's decrease decisions in the period before 1994. However, in the entire sample, which includes the post-1994 samples, we do find significant price drops before scheduled FOMC policy rate cut decisions. Also, their significance and impact on returns are greater in the post-1994 samples than in the entire period. From the results in Figure 2 and Table 3, it is natural to conclude that oil price drops before policy rate cuts stem from the post-1994 samples. Therefore, we use the dataset after February 1994 to investigate abnormal price movements.

4.2. Are price movements related to the magnitude of policy rate change?

In the previous sections, we find the price movements on the day before the scheduled FOMC announcements when the Committee decided to decrease the federal funds rate. In this section, we investigate whether the magnitude of the FOMC's policy changes influences pre-FOMC returns. Prior to our research, Kuttner (2001) used the federal funds futures rate to estimate the magnitude of the policy rate change. He constructed the unexpected policy rate change by using the difference between the federal funds futures rate on the FOMC announcement date and the day before, and he constructed the expected policy rate change as the policy rate change minus the unexpected policy rate change:

$$\Delta u_t = \frac{D}{D-d}\left(f_t^0 - f_{t-1}^0\right) \tag{2}$$

$$\Delta p_t = \Delta e_t + \Delta u_t \tag{3}$$

where Δu_t is the unexpected rate change at time t, Δp_t is the monetary policy change at time t, Δe_t is the expected rate change at time t, f_t^0 is the federal funds futures rate of the current month's contract at time t, d is the day of the FOMC announcement date in the current month, and D is the number of days in the current month. The expected policy rate change gauges the market's expectation of policy rate change, and it is defined as the actual policy rate change minus the unexpected rate change. Also, Gürkaynak et al. (2007) argued that the federal funds futures are the most appropriate among all other securities from which to forecast monetary policy.

To investigate whether the oil price return on pre-FOMC dates is affected by a monetary policy surprise that comes the next day, we conduct our regressions using the real policy rate change, the expected rate change, and the unexpected rate change,

$$r_t = \beta_0 + \beta_1 * \Delta RC_{t+1} + \beta_2 * \Delta RC_{t+1} * I^{+}_{\Delta RC_{t+1}} + \sum_i \beta_i X_{i,t} + \epsilon_t \qquad (4)$$

where ΔRC_{t+1} represents, in turn, the real policy, expected, and unexpected rate changes at $t+1$; $I^{+}_{\Delta RC_{t+1}}$ is a dummy variable equal to 1 if ΔRC_{t+1} has a positive value, otherwise it is 0; and $X_{i,t}$ are control variables that include the macroeconomic news surprises and the daily natural gas futures returns. The macroeconomic news surprises are defined as the difference between the actual announcements and the market's expectations divided by its sample standard error. Andersen et al. (2003) constructed this measure, and many other studies followed their method to construct the macroeconomic news surprise (e.g., Kilian & Vega, 2011, Chatrath et al., 2012, and others). The daily natural gas futures return is not related to any other control variables in this study, but it can explain the remaining part of the daily oil futures return that is not fully explained by the other control variables.[1]

Table 4 summarizes the results of the above regressions. In this table, we find that the oil price return can be affected by next day's policy rate changes. However, it should be problematic to understand this result as oil price predicts

[1]Mu (2007) and Basistha & Kurov (2015) also use a similar method to construct their regression model for the energy futures return.

Table 4
Oil price movements related to the magnitude and direction of policy rate changes.
This table contains results from the following regression:
$r_t = \beta_0 + \beta_1 * \Delta RC_{t+1} + \beta_2 * \Delta RC_{t+1} * I^{+}_{\Delta RC_{t+1}} + \sum_i \beta_i X_{i,t} + \epsilon_t$,
where r_t is the oil futures price return; ΔRC_{t+1} represents, in turn, the real policy, expected, and unexpected rate change at time $t+1$; $I^{+}_{\Delta RC_{t+1}}$ is a dummy variable equal to 1 if ΔRC_{t+1} has a positive value, otherwise it is 0; and $X_{i,t}$ are control variables. All specifications are derived from OLS using a Huber-White heteroskedasticity consistent covariance matrix. Robust standard errors are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
Constant	0.017 (0.030)	0.0198 (0.030)	0.016 (0.030)	0.018 (0.030)	0.016 (0.030)
Policy Rate Change	1.696** (0.793)	2.781*** (0.875)	-	-	-
Expected Rate Change	-	-	1.989*** (0.771)	2.959*** (0.804)	2.932** (1.197)
Unexpected Rate Change	-		−1.268 (3.038)	0.007 (2.800)	0.411 (5.271)
Positive Rate Change ×					
Policy Rate Change	-	−5.541* (2.828)	-	-	-
Expected Rate Change	-	-	-	−3.748* (2.089)	−3.781 (2.576)
Unexpected Rate Change	-	-	-	-	−6.894 (8.957)
Adjusted R^2	0.055	0.055	0.055	0.055	0.055

policy rate changes because it is not affected by unexpected policy rate changes observed at the next day, the scheduled FOMC announcement dates. The coefficients of Δu_{t+1} show no statistical significance. Meanwhile, the coefficient of the expected policy rate change is significantly positive, suggesting that the expected portion of the policy rate changes may have an effect on oil price returns instead of the unexpected portion. This result shows that the oil futures price is influenced by the next day's policy rate decisions at the scheduled FOMC meetings as much as the market expectations today. However, a positive expectation of policy rate changes for the FOMC's federal funds rate decisions has an asymmetric impact on oil price. The coefficients of $\Delta e_{t+1} * I^{+}_{\Delta RC_{t+1}}$ in columns (2) and (4) are significantly negative, and they are opposite to the coefficients of the expected rate change. As a result of the asymmetric effect of the positive expected policy rate change, the abnormal returns on the day before a policy rate rise are not captured in Table 2. To understand this phenomenon, we entertain two possible explanations. First, the oil futures price return may not be affected by a policy rate increase. If the policy rate increase is not threatening or a price increasing factor, then the oil price will not fluctuate under positive expectations. Second, the market's expectations of a policy rate increase may already be reflected in the oil price prior to pre-FOMC announcement dates because the market's expectations of policy rate decisions at the scheduled FOMC meetings exist at any time. If the oil price reflects changes in the market's expectation of a policy rate decision, then the response will not be duplicated. To find out why this phenomenon does not occur before a policy rate increase, we perform an additional test in the next section.

4.3. Do oil price returns reflect changes in expectation of the FOMC's monetary policy rate decisions?

To investigate our second explanation, that is, the market's expectations of a policy rate increase may already be reflected in the oil price prior to pre-FOMC announcement dates, we need the daily change in the market's expectation of the policy rate decision. However, the policy surprise measure can only capture shocks on the FOMC announcement dates. To meet our objective, we construct the change in the market's expectation of the next FOMC meeting, $CE1_t$, by extending the unexpected rate change at time t:

$$CE1_t = \frac{D1}{D1 - d1}\left(f1_t - f1_{t-1}\right) \tag{5}$$

where $f1_t$ is the federal funds futures rate of the month at time t when the next scheduled FOMC meeting is held, $d1$ is the day of the month of the next scheduled FOMC meeting, and $D1$ is the number of days in the month of the next scheduled FOMC meeting. Also, Gürkaynak et al. (2007) used an alternative measure that can gauge the change in expectations of the policy rate after the second following FOMC meeting.[2] Similar to the $CE1$, by extending this to a daily measure, we can estimate the change in the market's expectation for the policy rate decision at the second following FOMC meeting, $CE2_t$:

$$CE2_t = \frac{D2}{D2 - d2}\left(f2_t - f2_{t-1}\right) - \frac{d2}{D2 - d2}CE1_t \tag{6}$$

where $f2_t$ is the federal funds futures rate for the month when the second following FOMC meeting is held, $d2$ is the day of the FOMC date in the month when the second following FOMC meeting is held, $D2$ is the number of days

[2]We apply similar methods as used in Kuttner (2001). When $D1$ minus $d1$ is less than 4, the unscaled daily differences for the next month are used.

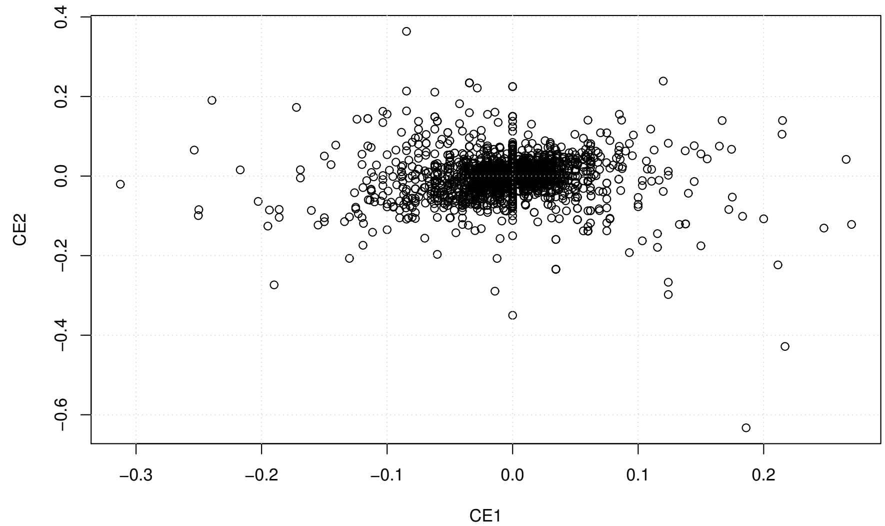

Fig 3. Scatterplot of $CE1$ and $CE2$
This figure compares $CE1$ and $CE2$ based on 5492 observations.

in the month when the second scheduled FOMC meeting is held, and $CE1_t$ is the change in the market's expectation for the next FOMC meeting. Figure 3 compares these two measures, $CE1_t$ and $CE2_t$, in a scatterplot. Similar to the results of Gürkaynak et al. (2007), by using the unexpected rate changes on the scheduled FOMC meeting days, the daily measures of the change in expectations are strongly correlated with each other, and they have a very significant correlation coefficient (0.25). To capture the change in the market's expectation of the policy rate for relatively long periods, the change in the market's expectation of the monetary policy path, the CEP, can be used. It is defined as the daily change in the one-year-ahead eurodollar interest rate futures. Hausman & Wongswan (2011) also used a similar measure constructed from the eurodollar interest rate futures; however, it only includes intraday changes around the FOMC announcements. Three policy rate expectation change measures are used in this study – $CE1$, $CE2$, and CEP – which capture the changes in monetary policy expectations within different periods. Similar to the $CE2$, the CEP is also strongly correlated with $CE1$ and $CE2$, suggesting that the CEP also contains information about changes in the near future expectation, which are the $CE1$ and $CE2$. To observe the true path of changes in expectation, it is necessary to remove information from the previous period. For that reason, we construct adjusted measures $CE2^{adj}$ and CEP^{adj}, which are the residuals from the following regressions:

$$CE2_t = \beta_0 + \beta_1 * CE1_t + CE2_t^{adj}, \tag{7}$$

$$CEP_t = \beta_0 + \beta_1 * CE1_t + \beta_2 * CE2_t^{adj} + CEP_t^{adj}, \tag{8}$$

where $CE2_t^{adj}$ is the adjusted $CE2$ and CEP_t^{adj} is the adjusted CEP at time t. Because the expectation in the near future should not be affected by that in the distant future, it is reasonable to say that the correlated portions of $CE1$ and $CE2$ are from $CE1$. Similarly, some portion of CEP, which is correlated with $CE1$ or $CE2$, is from changes in the near future expectation. Table 5 shows the results of the following regression:

$$r_t = \beta_0 + \beta_1 * CE1_t + \beta_2 * CE2_t^{adj} + \beta_3 * CEP_t^{adj} + \sum_i \beta_i X_{i,t} + \epsilon_t, \tag{9}$$

where $CE2_t^{adj}$ is the adjusted $CE2$, CEP_t^{adj} is the adjusted change in the market's expectation of the monetary path that is estimated by the one-year-ahead eurodollar rate, and the control variables are the same as in Table 4. Consistent with the hypothesis, the market's expectations of policy rate changes are already reflected in the oil price during non-FOMC announcement periods. A 10 basis points increase in the expectation of the policy rate decision at the following FOMC meeting causes an approximate 0.4 percent increase in the crude oil price. The results show a significantly positive coefficient of $CE1$ at

Table 5
Relationships between changes in expectations of the monetary policy rate and oil price movements.
This table contains results from the following regression:
$r_t = \beta_0 + \beta_1 * CE1_t + \beta_2 * CE2_t^{adj} + \beta_3 * CEP_t^{adj} + \sum_i \beta_i X_{i,t} + \epsilon_t$,
where r_t is the oil futures price return, $CE1_t$ and $CE2_t$ are the change in expectations of the monetary policy rate after the next and second following FOMC meeting, CEP_t is the change in the market's expectation of the monetary path that is estimated by the one-year-ahead eurodollar rate, and $X_{i,t}$ are control variables. This table contains 5491 observations. $CE1_t$ and $CE2_t$ are used in columns (1) and (2). $CE2_t^{adj}$ and CEP_t^{adj} are used in columns (3) and (4). All specifications are derived from OLS using a Huber-White heteroskedasticity consistent covariance matrix. Robust standard errors are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)
Constant	0.022 (0.030)	0.020 (0.028)	0.021 (0.030)	0.022 (0.030)
$CE1$	4.001*** (1.138)	4.017** (1.141)	4.017*** (1.127)	4.033*** (1.129)
$CE2$	-	2.099** (0.848)	-	2.112** (0.838)
CEP	-	-	1.285** (0.577)	1.291** (0.578)
Adjusted R^2	0.057	0.058	0.058	0.059

4.001. The change in the expectations of the policy rate decisions at the second following FOMC meeting and the change in monetary path expectations, $CE2$ and CEP, also have positive effects on oil price. Finally, this result supports the explanation that the oil price already reflects the market's expectations of monetary policy rate decisions prior to the scheduled FOMC meetings.[3]

Our previous results show that the oil futures price returns positively reflect changes in the expectation of monetary policy decisions. Prior studies have argued that the target surprise negatively affects oil price (but only after unscheduled FOMC meetings) and that the path surprises have a positive but not significant relation with oil price after the FOMC meetings (Basistha &

[3]Three policy rate expectation change measures, $CE1$, $CE2$, and CEP, have symmetric effects on the oil price return, but the results are not reported. These results are available upon request.

Kurov, 2015 and Rosa, 2014). The target surprise measures unexpected monetary policy changes in the FOMC's current policy and the path surprise includes unexpected changes in future monetary policy and the FOMC's perspective on the macroeconomic situation. To investigate the impact of monetary policy on oil price, we need measures that can estimate surprises without endogeneity problems. Following Gürkaynak et al. (2005), two surprise measures, the target surprise and the path surprise, are used to determine the relationship between monetary policy and oil price within a high-frequency framework. Meanwhile, the change in expectation of the monetary policy decision measures, CE1, CE2, and CEP, which we use in this study are not constructed to measure true surprises. Since they are not surprise measures, information about the macroeconomic situation is included in the CE measures. The FOMC can decide to raise its policy rate in certain circumstances, such as when the U.S. economy is strong enough for the implementation of contractionary fiscal policies. Hence, increased policy rate expectations involve upbeat news of the economic situation, and it appears that positive changes in policy rate expectations increase the crude oil price. Bernanke & Kuttner (2005) suggest a similar argument – the FOMC's policy rate cut may be a signal that indicates weaker-than-expected economic growth. Therefore, a policy rate cut seems to be related to oil price decline, which means that it captures the positive effect of the policy rate change on the oil price. Moreover, similar to the result of Rosa (2011), who found that path surprises positively affect the exchange value of the U.S dollar against other currencies, our measures, which can be considered as daily path changes, affect the U.S. dollar value. Therefore, considering the dollar value can improve the significance and magnitude of the results. To control for the dollar value, we use the trade-weighted U.S. dollar index for major currencies as a proxy for the dollar value. It supports the finding by Rosa (2013), who shows that the oil

Table 6
Effect of the expected policy rate change on the oil price after controlling for the CE measures. This table contains the results from the following regression:
$r_t = \beta_0 + \beta_1 * CE1_t + \beta_2 * CE2_t + \beta_3 * CEP_t + \beta_4 * \Delta e_t + \beta_5 * \Delta e_t * I^{+}_{\Delta e_t} + \sum_i \beta_i X_{i,t} + \epsilon_t$, where r_t is the oil futures price return, $CE1_t$ and $CE2_t$ are the change in expectations of the monetary policy rate after the next and second following FOMC meetings, CEP_t is the change in the market's expectation of monetary path that is estimated by the one-year-ahead eurodollar rate, Δe_t is the expected policy rate change, $I^{+}_{\Delta e_t}$ is a dummy variable equal to 1 if Δe_t has a positive value, otherwise it is 0, *Dollar Index* is the trade-weighted U.S. dollar index for major currencies, and $X_{i,t}$ are control variables. This table includes 5491 observations. All specifications are derived from OLS using a Huber-White heteroskedasticity consistent covariance matrix. Robust standard errors are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
Constant	0.024 (0.030)	0.025 (0.028)	0.022 (0.030)	0.024 (0.030)	0.023 (0.030)
CE1	3.923*** (1.137)	3.940*** (1.141)	3.935*** (1.126)	3.952*** (1.128)	4.381*** (1.106)
CE2	-	2.015* (0.847)	-	2.026** (0.836)	2.351*** (0.842)
CEP	-	-	1.324** (0.576)	1.329** (0.577)	1.850*** (0.556)
Expected rate change	2.818*** (0.861)	2.720*** (0.872)	2.923*** (0.844)	2.825*** (0.854)	3.280*** (0.996)
Positive rate change × Expected rate change	−3.754* (2.031)	−3.561* (2.014)	−3.821* (2.012)	−3.628* (1.995)	−4.094** (2.042)
Dollar Index	-	-	-	-	−0.939*** (0.087)
Adjusted R^2	0.058	0.059	0.059	0.060	0.090

price quoted in EUR is significantly and positively affected by the monetary path surprise on the FOMC dates within a high-frequency framework.

Table 6 shows that even though the oil price reflects the change in the market's expectation of the policy rate decision, it is still affected by the expected policy rate change in pre-FOMC dates. Also, the asymmetric effect of positive expected policy rate changes does not disappear. All of the coefficients for the measures of changes in expectation of the policy rate have significantly positive values but so do the coefficients for Δe_t and $\Delta e_t * I^{+}_{\Delta e_t}$. The magnitude and significance of these asymmetric effects are greater when we control for the dollar value.

4.4. Conditional volatility in the pre-FOMC announcement periods

Results from the previous analysis show that oil price returns decrease as a result of the negative expectation of federal policy rate changes in the pre-FOMC dates. By contrast, during the same periods, a positive expectation of policy rate changes shows a significant and opposite impact, which attenuates the expected policy rate change effect on the oil price returns. However, this result is not because the oil price is not affected by positive expectations. Positive expectations are already reflected in the oil price. Three measures that capture daily changes in the market's expectation for the policy rate have a symmetric effect on the oil price return. Next, we consider the conditional volatility movements in the periods before the FOMC announcement dates.

Volatility movements in the pre-announcement dates – so-called pre-announcement effects – have been analyzed in other studies. For instance, Jones et al. (1998) used sample average volatilities and found that Treasury bond market volatility decreases on the day before macroeconomic announcements. Stock market volatility on pre-announcement dates is also lower than other periods, but government and corporate bond return volatilities are higher on pre-announcement dates (Bomfim, 2003 and Brenner et al., 2009). We use the GARCH specification as in Bollerslev (1986) and estimate the conditional volatility of oil markets during the pre-FOMC periods using a GARCH(1,1) model that has similar specifications as those used by Vlastakis & Markellos (2012):

$$r_t = \mu + \sum_i \beta_i X_{i,t} + u_t \tag{10}$$

$$u_t = \sqrt{h_t}\,\epsilon_t \tag{11}$$

$$E[\epsilon_t \mid \Omega_{t-1}] = 0 \text{ and } E[\epsilon_t^2 \mid \Omega_{t-1}] = 1 \tag{12}$$

$$h_t = \omega + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 h_{t-1} + s_t \tag{13}$$

where $X_{i,t}$ includes the lagged returns and other explanatory variables, u_t stands for the unexplained return movements, and s_t measures the magnitude of conditional variance. To capture volatility movements in pre-FOMC periods, we set $s_t = \delta_1 I_t^{FOMC} + \delta_2 I_{t-1}^{FOMC} + \delta_3 I_{t+1}^{FOMC}$, where I_t^{FOMC} is a dummy variable equal to 1 if the scheduled FOMC meeting is held at time t and is 0 otherwise, I_{t-1}^{FOMC} is a dummy variable equal to 1 if the scheduled FOMC meeting is held at time $t-1$ and is 0 otherwise, and I_{t+1}^{FOMC} is the same as the pre-FOMC dummy already defined. Negative δ_3 can be interpreted as the decrease in oil price volatility in pre-FOMC periods, that is, the so-called "calm before the storm" effect.

Table 7 includes the coefficient estimates of the model and their robust standard errors as computed in Bollerslev & Wooldridge (1992). Model 1 estimates the pre-announcement effect of FOMC announcements on the oil market, and s_t is constructed as $s_t = \delta_1 I_t^{FOMC} + \delta_2 I_{t-1}^{FOMC} + \delta_3 I_{t+1}^{FOMC}$. Contrary to the results for the stock markets, we find that conditional volatility on the oil price increases on the pre-FOMC dates. The coefficient for the pre-FOMC dummy is significantly positive at 0.800.

Next, we investigate the asymmetric effect of the policy rate expectations on conditional volatility. To capture asymmetric volatility movements by policy rate expectations on pre-FOMC dates, we set s_t as $s_t = \gamma_1 I_{t+1}^{FOMC} I_{\Delta e_t}^{+} +$

Table 7
Conditional volatility during the pre-FOMC periods.
This table contains estimates from the GARCH(1,1) model:
$r_t = \mu + \sum_i \beta_i X_{i,t} + u_t$
$u_t = \sqrt{h_t}\epsilon_t$
$E[\epsilon_t \mid \Omega_{t-1}] = 0 \; and \; E[\epsilon_t^2 \mid \Omega_{t-1}] = 1$
$h_t = \omega + \alpha_1 \epsilon_{t-1}^2 + \alpha_2 h_{t-1} + s_t$
For model 1, $s_t = \delta_1 I_t^{FOMC} + \delta_2 I_{t-1}^{FOMC} + \delta_3 I_{t+1}^{FOMC}$
For model 2, $s_t = \gamma_1 I_{t+1}^{FOMC} I_{\Delta e_t}^{+} + \gamma_2 I_{t+1}^{FOMC} I_{\Delta e_t}^{-}$
where I_t^{FOMC} is a dummy variable equals to 1 if the scheduled FOMC is held at time t and is 0 otherwise, I_t^p is a dummy variable equals to 1 if the expectation of the policy rate change is positive and is 0 otherwise, I_t^n is a dummy variable equals to 1 if the expectation of the policy rate change is negative and is 0 otherwise, and $X_{i,t}$ includes the lagged returns and other control variables. The sample includes the crude oil futures returns from February 1994 to February 2016. Robust standard errors from Bollerslev & Wooldridge (1992) are shown in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Model 1	Model 2
μ	0.036^{***} (0.026)	0.035^{***} (0.026)
ω	0.013^{***} (0.015)	0.027^{***} (0.013)
α_1	0.053^{***} (0.010)	0.052^{***} (0.011)
α_2	0.942^{***} (0.011)	0.942^{***} (0.012)
δ_1	-0.137 (0.887)	-
δ_2	-0.031 (0.775)	-
δ_3	0.800^{*} (0.433)	-
γ_1	-	0.342 (0.296)
γ_2	-	0.965^{**} (0.488)

$\gamma_2 I_{t+1}^{FOMC} I_{\Delta e_t}^{-}$ in model 2, where $I_{\Delta e_t}^{+}$ is a dummy equal to 1 if the expectation of the policy rate change is positive and is 0 otherwise, and $I_{\Delta e_t}^{-}$ is 1 if the expectation of the policy rate change is negative and is 0 otherwise. In other words, a positive and significant γ_1 means that the conditional volatility increases on pre-FOMC dates, when the market expects the policy rate to rise. Model 2 in the Table 7 shows the asymmetric conditional volatility movements as a result of policy rate expectations. When market participants expect that the FOMC will cut its policy rate at the next day's scheduled FOMC meeting, the volatility of oil prices goes up. γ_2 is significantly positive, whereas γ_1 is a positive but insignificant coefficient. This means that the conditional volatility increase phenomenon only occurs if there is a negative expectation of a policy rate change.[4] From the results, the volatility feedback effect may be a possible explanation for the oil price drop before scheduled FOMC meetings only if there is a negative policy rate change expectation. In the U.S. stock market, there is a negative contemporaneous relationship between returns and volatility, which is called asymmetric volatility (Engle & Ng, 1993, Campbell & Hentschel, 1992, and others). Existing studies have tried to explain asymmetric volatility through the volatility feedback effect. Volatility feedback indicates that increased volatility raises future expected volatility, which then leads to an increase in required returns. Consequently, asset prices immediately decrease (French, 1987). Campbell & Hentschel (1992), Wu (2001), and many other researchers find that there is a significant volatility feedback effect in equity markets and it is important to determine asymmetric volatility.

[4]We also tested the exponential GARCH model (Nelson, 1991) and the GJR model (Glosten et al., 1993), and the results were not different from those in Table 7.

5. Conclusion

In this study, we find that the oil market has experienced an approximate 1 percent drop on the day before the scheduled FOMC announcements cut the monetary policy rate, and this phenomenon only exists in the post-1994 period. Moreover, these price drops are caused by the expected monetary policy rate changes, not by the unexpected portion of them. This is the first study that investigates the relationship between oil price returns and the expectation of monetary policy rate changes on pre-FOMC periods. However, it is difficult to believe that the expected monetary policy rate change directly affects the oil price because the expected monetary policy rate change can be treated as the sum of daily changes in policy rate expectations. It is natural that oil price is affected by the change in policy rate expectations but not by the expectations themselves. We find a positive relationship between oil price and the change in expectations based on the following policy rate decision measures: $CE1$, $CE2$, and CEP. A 100 basis points rise in expectations of the following FOMC's policy rate decision is associated with an approximate 4 percent increase in the crude oil price and vice versa. As mentioned, macroeconomic news can affect the CE measures and oil price contemporaneously. For this reason, the result does not mean that there is an exact relationship between monetary policy and oil price. After controlling for daily changes, oil price is still influenced by the expected policy rate change. Finally, using GARCH estimation, we find that the conditional volatility only increases on pre-FOMC dates if the expectation of the policy rate change is negative. This could be an evidence of the volatility feedback effect, which means that increased conditional volatility causes the oil price to drop.

References

Andersen, T. G., Bollerslev, T., Diebold, F. X., & Vega, C. (2003). Micro effects of macro announcements: Real-time price discovery in foreign exchange. *The American Economic Review 93*, 38–62.

Balduzzi, P., Elton, E. J., & Green, T. C. (2001). Economic news and bond prices: evidence from the US treasury market. *Journal of Financial and Quantitative Analysis 36*, 523–543.

Barsky, R. B., & Kilian, L. (2004). Oil and the macroeconomy since the 1970s. *The Journal of Economic Perspectives 18*, 115–134.

Basistha, A., & Kurov, A. (2015). The impact of monetary policy surprises on energy prices. *Journal of Futures Markets 35*, 87–103.

Bernanke, B. S., & Kuttner, K. N. (2005). What explains the stock market's reaction to federal reserve policy? *The Journal of Finance 60*, 1221–1257.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics 31*, 307–327.

Bollerslev, T., & Wooldridge, J. M. (1992). Quasi-maximum likelihood estimation and inference in dynamic models with time-varying covariances. *Econometric Reviews 11*, 143–172.

Bomfim, A. N. (2003). Pre-announcement effects, news effects, and volatility: Monetary policy and the stock market. *Journal of Banking & Finance 27*, 133–151.

Brenner, M., Pasquariello, P., & Subrahmanyam, M. (2009). On the volatility and comovement of us financial markets around macroeconomic news announcements. *Journal of Financial and Quantitative Analysis 44*, 1265–1289.

Brusa, F., Savor, P., & Wilson, M. (2016). One central bank to rule them all. Working paper, Oxford University.

Campbell, J. Y., & Hentschel, L. (1992). No news is good news: An asymmetric model of changing volatility in stock returns. *Journal of Financial Economics 31*, 281–318.

Chatrath, A., Miao, H., & Ramchander, S. (2012). Does the price of crude oil respond to macroeconomic news? *Journal of Futures Markets 32*, 536–559.

Engle, R. F., & Ng, V. K. (1993). Measuring and testing the impact of news on volatility. *Journal of Finance 48*, 1749–1778.

French, Kenneth R and Schwert, G William and Stambaugh, Robert F. (1987). Expected stock returns and volatility. *Journal of financial Economics 19*, 3–29.

Frankel, J. A. (2006). The effect of monetary policy on real commodity prices. *National Bureau of Economic Research Working Paper No. 12713*.

Glosten, L. R., Jagannathan, R., & Runkle, D. E. (1993). On the relation between the expected value and the volatility of the nominal excess return on stocks. *Journal of Finance 48*, 1779–1801.

Gürkaynak, R. S., Sack, B., & Swansonc, E. T. (2005). Do actions speak louder than words? the response of asset prices to monetary policy actions and statements. *International Journal of Central Banking 1*, 55–94.

Gürkaynak, R. S., Sack, B. P., & Swanson, E. T. (2007). Market-based measures of monetary policy expectations. *Journal of Business & Economic Statistics 25*, 201–212.

Hausman, J., & Wongswan, J. (2011). Global asset prices and fomc announcements. *Journal of International Money and Finance 30*, 547–571.

Jones, C. M., Lamont, O., & Lumsdaine, R. L. (1998). Macroeconomic news and bond market volatility. *Journal of Financial Economics 47*, 315–337.

Kilian, L., & Vega, C. (2011). Do energy prices respond to us macroeconomic news? a test of the hypothesis of predetermined energy prices. *Review of Economics and Statistics 93*, 660–671.

Kuttner, K. N. (2001). Monetary policy surprises and interest rates: Evidence from the fed funds futures market. *Journal of Monetary Economics 47*, 523–544.

Lucca, D. O., & Moench, E. (2015). The pre-fomc announcement drift. *Journal of Finance 70*, 329–371.

Mu, X. (2007). Weather, storage, and natural gas price dynamics: Fundamentals and volatility. *Energy Economics 29*, 46–63.

Nelson, D. B. (1991). Conditional heteroskedasticity in asset returns: A new approach. *Econometrica 59*, 347–370.

Rosa, C. (2011). The high-frequency response of exchange rates to monetary policy actions and statements. *Journal of Banking & Finance 35*, 478–489.

Rosa, C. (2013). The high-frequency response of energy prices to monetary policy: understanding the empirical evidence. *Federal Reserve Bank of New York Staff Reports No. 598.*

Rosa, C. (2014). The high-frequency response of energy prices to us monetary policy: Understanding the empirical evidence. *Energy Economics 45*, 295–303.

Vlastakis, N., & Markellos, R. N. (2012). Information demand and stock market volatility. *Journal of Banking & Finance 36*, 1808–1821.

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica 48*, 817–838.

Wu, G. (2001). The determinants of asymmetric volatility. *Review of Financial Studies 14*, 837–859.