Does Quantitative Easing Increase the Risk of Long-Term Inflation Expectations Unanchoring?

By

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Abstract

This paper[1] investigates the cost of Quantitative Easing in the U.S. by focusing on its lasting effects on long-term inflation expectations. I use a high-frequency approach to identify the QE components of each FOMC announcement that have the greatest explanatory power in price change of federal funds futures and eurodollar futures. Then I use them as external instruments for monetary policy shocks in VAR model and estimate the impulse response of inflation expectations. The evidence shows that unexpected QE shocks can have large instant effects on both short-term and long-term inflation expectations. One standard deviation of QE shock can lead to a 0.01 percent change in long-term inflation expectations and around 21 percent variation in long-term inflation expectations is attributed to the QE shock. In contrast, long-term inflation expectations sustain a lasting influence for an extended period while effects die out soon for short-term expectations, which can lead to the unanchoring of inflation expectations.

Keywords Monetary policy, Quantitative easing, High-frequency, External instrument, inflation expectation

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1 Introduction

Prior to the 2008 global financial crisis, central banks mainly depended on targeting short-term interest rates to influence financial conditions and the overall economy. However, this conventional monetary policy became ineffective since December 2008 when the Federal Open Market Committee (FOMC) reduced the federal funds rate(ffr) to its effective zero lower bounds (ZLB). This situation indicates that nominal interest rates were already near zero, preventing central banks from further cutting rates to boost a deteriorating economy during the recession. Also recently, the Fed cuts the short-term interest rates to zero again due to the effects of covid shock in 2020 and raises it after 2022. As a result, central banks started using unconventional monetary policies, with quantitative easing (QE) being one of the most well-known approaches.

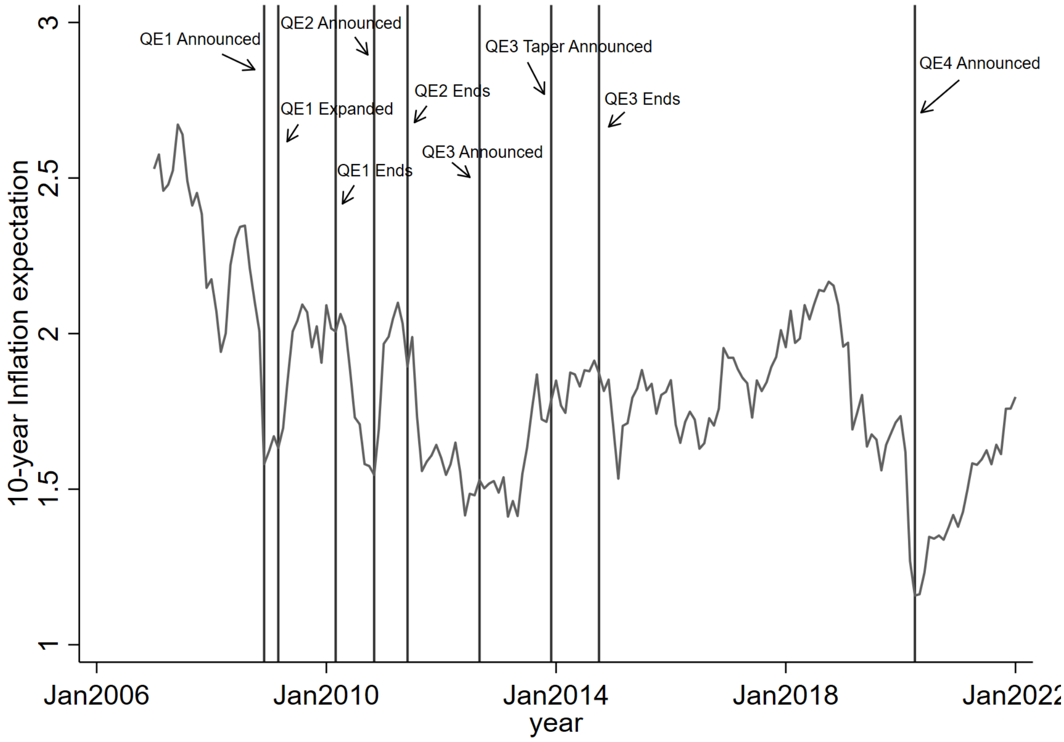
QE policy refers to large-scale purchases of Treasuries or other securities such as MBS by a central bank so that they can pump liquidity into short-term markets. During the Great Recession, the Federal Reserve began to rely on QE for the first time: purchasing assets for the Fed's portfolio and financing by the creation of reserves in the banking system. The objective of this policy is to reduce long-term interest rates, increase liquidity in the short-term market, and ease credit spreads for all bonds. There are three rounds of QE after the financial crisis: QE1 2009-2010, QE2 2010-2011, QE3 2012-2014, and a more aggressive round of QE after the covid-19 pandemic. The latter led to a twofold increase in the size of the Federal Reserve's balance sheet and greatly surprising the market. Since the slow recoveries of the economy and low-interest rates are becoming commonplace, an increased reliance on QE policy can be expected in the future. Therefore it is of great importance to analyze potential effects of QE.

So far there have been a bunch of studies evaluating the efficacy of QE, through signaling channel (Bauer and Rudebusch, 2014) and portfolio balance channel (Thornton, 2012). However, the potential cost of QE has received less consideration. Kandrac (2018) shows that large-scale MBS purchases by the Fed since 2011 have resulted in deterioration in measures of liquidity and market functioning. He finds that MBS purchases by Fed can adversely affect average trading volume, trade sizes, and the number of trades. Levin et al. (2022) did a similar work by focusing on the most recent round of QE.

Another potential cost of QE pointed out by the Fed's annual report is that it may undermine public confidence in the Fed and increase the risk that long-term inflation expectations become unanchored. The topic has been much less discussed since, first, it is usually extremely hard to directly measure the effects of QE, and second, long-term inflation expectations have remained stable for a long time after 2012 but started to fluctuate wildly only after covid-19 pandemic. However, the issue deserves more in-depth exploration not only because of the increasingly frequent use of QE policy in the future but also because there is some empirical evidence that long-term inflation expectations have been de-anchored during the financial crisis (Galati et al., 2018) and have not been re-anchored ever since (Nautz and Strohsal, 2015). Since the anchoring properties of long-term inflation expectations is an important measure of monetary policy credibility, it is thus essential to analyze how inflation expectations respond to monetary policies and how the re-anchoring channel work. In addition, it is clear that QE is significantly correlated with long-term inflation expectations. Figure 1 presents the trend for 10-year inflation expectations[2] with 4 rounds of QE timelines. We can see that inflation expectations increase rapidly immediately after the QE announcement of each round. It also becomes relatively stable over a long period between QE3 and QE4, and starts to vary again closely

[2]10-Year Expected Inflation data estimated by FRED. Their estimates are calculated with a model that uses Treasury yields, inflation data, inflation swaps, and survey-based measures of inflation expectations.

Figure 1: 10-year inflation expectation[1] and QE Announcements



Note: Figire 1 plots the trend of 10-year inflation expectation from 2007Jan to 2022Jan with the timeline of four rounds of QE announcement

following the QE4 announcement. The trend indicates a strong correlation between the variation of long-term inflation expectations and QE.

Therefore in this paper, I am going to analyze the long-term effects of QE shock on survey-based inflation expectations. First, I employ the high-frequency method proposed by Swanson (2021) to decompose and identify monetary policy shocks into three components, labeled as QE, federal funds rate, and forward guidance by looking at the changes in asset prices of federal funds futures and eurodollar futures before and after each FOMC meeting. I extract the first three principal components that had the greatest explanatory power for these changes but do not have any structural interpretation. That is, the first three factors that can best explain the market's reaction to surprising news released from FOMC

[1]10-Year Expected Inflation data estimated by FRED. Their estimates are calculated with a model that uses Treasury yields, inflation data, inflation swaps, and survey-based measures of inflation expectations.

meeting. Then I rotate three factors with a unique orthogonal matrix so that factors after rotation correspond to the surprise changes in the federal funds rate, forward guidance, and QE, respectively.

With these identified factors, I mainly focus on the QE factor and fit it into VAR models with inflation expectation variables. First, I use QE factor as an external instrument for monetary shocks in a set of VARs, including both variables of survey-based short-term inflation expectations and long-term inflation expectations. Inflation data is collected from the Michigan Consumer Survey, and I use expected changes in prices during the next year for short-term inflation expectations and expected changes in prices during the Next 5 Years for long-term inflation expectations. The estimated impulse response shows that both short-term and long-term inflation expectations increase immediately after the QE shock. While short-term inflation expectations have a larger increase than long-term, it also decreases faster and the effect vanishes in the long term. In contrast, after a sharp immediate increase in the current period, long-term inflation expectations tend to suffer a consistent effect that at least last for a long time. That is, the surprising QE shock will make the public not only expect a current increase in inflation but also further worry about the future price increase and lead to a significant decrease in the market's confidence. Then in the comparison model, I put the QE factor directly in the VAR model and identify using parameter restrictions. I also test the result using the local projection–instrumental variable approach since Plagborg-Møller and Wolf (2021) claim that the impulse responses in the LP-IV model can also be calculated using a recursive VAR. All three models provide similar results.

The paper is organized in the following structure: Section 2 discusses in detail the high-frequency identification strategy for Quantitative Easing, explains the model of principal components and lists identification assumptions. In section 3, I specify various statistical models and section 4 is a comprehensive description of the dataset used and present estimation results. In section 5, I point out some potential issues and remedies. Section 6 concludes.

2 Identification

I identify the effect of surprising news about quantitative easing for each FOMC meeting, mainly following the setup of Swanson (2021) and extending the sample period from 2019 to March 2022.

Consider the factor model:

$$X = F\Lambda + \eta \tag{1}$$

where X is a $T \times n$ matrix representing asset prices before and after each FOMC meeting. F is a $T \times k$ matrix representing k latent factors, Λ is a $k \times n$ matrix of factor loadings. $T = 276$ is the number of observations and $n = 5$ is the number of assets I used to capture unexpected changes caused by FOMC meeting. The five assets chosen are federal funds futures contracts that expire in the month of current FOMC meeting and next FOMC meeting, and eurodollar futures contracts that will mature 3,4,5 quarters after each FOMC meeting. I use federal funds futures contracts to measure unexpected changes in market investors' expectation of future interest rates in one to three months and eurodollar futures contracts to measure investors' expectations over 9 to 15 months. I collect the closing price of all these five assets, calculate the daily change on the day of each FOMC announcement and standardize to have zero mean and variance of one.

The first three principal components extracted from X are denoted as $F = [F_1, F_2, F_3]$. With a standard algorithm, this non-parametric method generates vectors that have the largest explanatory power for the variation in X but may not have a structural interpretation. Following Swanson (2021)

$$X = \widetilde{F}\widetilde{\Lambda} + \eta \tag{2}$$

$$\widetilde{F}_{T\times 3} = F_{T\times 3}U_{3\times 3} \tag{3}$$

$$\widetilde{\Lambda} = U'\Lambda \tag{4}$$

I find an orthogonal matrix U to rotate F, so that the resulting columns in rotated matrix $\widetilde{F}$ can be interpreted as unexpected changes in the federal funds rate, forward guidance and QE, respectively.

To pin down the unique rotation matrix U, Swanson (2021) proposes three structural restrictions:

Restriction 1: Forward guidance factor has no influence on the expectation of current federal funds rate $x1$

$$\widetilde{\Lambda}_{2,1} = 0 \tag{5}$$

Restriction 2: QE factor $\widetilde{F}_3$ has no influence on expectation of current federal funds rate $x1$

$$\widetilde{\Lambda}_{3,1} = 0 \tag{6}$$

Restriction 3: Minimize the variance of QE factor $\widetilde{F}_3$ in pre-QE periods (Feb 1990 -

Oct 2008) given the first round of QE in the US is announced in Nov 2008.

$$\min_{U_3} U_3'(F^{pre})'F^{pre}U_3 \tag{7}$$

Let U_3 denote the third column of the U matrix. $\widetilde{\Lambda}_{i,j}$ denote the element of matrix $\widetilde{\Lambda}$, and F^{pre} is the sub part of matrix F, containing values of F from Feb 1990 to Oct 2008. These three restrictions uniquely pin down a rotation matrix U and rotated factor $\widetilde{F}$ acquires its structural interpretation.

High-frequency identification has some potential problems. As pointed out in Rossi (2021), any price change before and after the FOMC meeting is attributed to unexpected changes in monetary policy. It is also possible that new information about the economy is conveyed in the FOMC announcements that are not related to monetary policy. If the central bank has more information than the private sector, the effects of monetary policy may be overestimated. To address the issue, I fit the VAR model using QE factor as an external instrument and test with restricted VAR and local projection.

3 Methodology

3.1 VAR with external instrument

Proposed by Mertens and Ravn (2013) and developed by Gertler and Karadi (2015), the VAR-external instrument approach uses identified monetary policy shocks as external instruments for residuals. Consider a VAR model:

$$W_t = \sum_{j=1}^{4} B_j W_{t-j} + u_t,\ \ u_t = S\epsilon_t \tag{8}$$

$$E[u_t u_t'] = SE[\epsilon_t \epsilon_t^{'}]S' = SS' = \Sigma \tag{9}$$

$$u_t = (u_t^p, u_t^q)',\ \ \epsilon_t = (\epsilon_t^p, \epsilon_t^q)' \tag{10}$$

I order the monetary policy indicator the first variable in W_t so that the first error in u_t corresponds to the monetary policy shock that we are interested in. I use two-year treasury yield here as the policy indicator since it is shown that it has significant effects on long-term bond returns (Gertler and Karadi, 2015). Other variables inside W_t include one-year inflation expectation, five-year inflation expectation, actual inflation, unemployment rate, and industrial production. u_t is the reduced form shock with a covariance matrix Σ which is usually not identity. Since u_t can be contemporaneously correlated, we decompose it into ϵ_t with an identity covariance matrix. To draw the impulse response of monetary policy shock that we are interested in, we only need to estimate the first column of matrix S since the left columns only correspond to the effects of other non-monetary shocks.

We only focus on monetary policy shock ϵ_t^p and the corresponding policy indicator is two-year treasury yields in this case. Similarly, divide $s = (s^p, s^q)'$ which is the column in S corresponding to the monetary policy shock ϵ_t^p. p means policy indicator and q denotes other variables. To use QE factor identified before as an instrument Z_t here, we need to impose instrument conditions

$$Z_t = \tilde{F}_{3,t} \tag{11}$$

$$E[Z_t \epsilon_t^p] = \phi \tag{12}$$

$$E[Z_t \epsilon_t^q] = 0 \tag{13}$$

We only need to estimate the first column $s = (s^p, s^q)'$ in S since they are related to monetary policy which we are interested in. In this case we have six variables so can divide $s = (s_{11}, \cdots, s_{61})$ where the covariance matrix can be grouped into

$$\left[\begin{array}{c|ccccc} s_{11} & & & S_{12} & & \\ \hline s_{21} & \ddots & & & & \\ s_{31} & & \ddots & & & \\ s_{41} & & & S_{22} & & \\ s_{51} & & & & \ddots & \\ s_{61} & & & & & \ddots \end{array}\right] \tag{14}$$

Then we can use a two-stage least square approach to get an estimation for s. First, we run OLS regressions on the reduced-form VAR model. Calculate the reduced-form residual $\tilde{u}_t = (\tilde{u}_t^p, \tilde{u}_t^q)'$ and estimate the covariance matrix Σ. Second, in the first-stage estimation, we regress $\tilde{u}_t^p$ on Z_t and get the fitted value $\hat{u}_t^p$ which excludes variation from other policy shocks. And it tests the instrument relevance. In other words the variation in $\hat{u}_t^p$ only comes from ϵ_t^p. Then in the second stage we do the regression

$$\tilde{u}_t^q = \frac{s^q}{s^p} \hat{u}_t^p + \zeta_t \tag{15}$$

The instrument exogeneity condition ensures that $E(\hat{u}_t^p \zeta_t) = 0$ so that the estimation of $\frac{s^q}{s^p}$ is consistent. Finally we can estimate s using estimation of $\frac{s^q}{s^p}$ and covariance matrix Σ estimated before:

$$\Sigma = \begin{bmatrix} \Sigma^p & \Sigma_{12} \\ \Sigma^q & \Sigma_{22} \end{bmatrix}, S = \begin{bmatrix} s^p & s_{12} \\ s^q & s_{22} \end{bmatrix} \tag{16}$$

$$(s^p)^2 = \Sigma^p - s_{12}s_{12}' \tag{17}$$

$$s_{12}s_{12}' = (\Sigma^q - \frac{s^q}{s^p}\Sigma_{11})'Q^{-1}(\Sigma^q - \frac{s^q}{s^p}\Sigma_{11}) \tag{18}$$

$$Q = \frac{s^q}{s^p}\Sigma^p(\frac{s^q}{s^p})' - (\Sigma^q(\frac{s^q}{s^p})' + \frac{s^q}{s^p}\Sigma^{q'}) + \Sigma_{22} \tag{19}$$

After pining down the vector s and getting estimates for coefficients B_j, we can draw the impulse response to QE shocks.

3.2 Restricted VAR

Alternatively, we can run a VAR directly using QE factor as the monetary policy indicator. That is, we expand the previous regressors with Z_t. Now the equation becomes:

$$\begin{bmatrix} Z_t \\ W_t \end{bmatrix} = \sum_{p=1}^{P} \begin{bmatrix} 0 & 0 \\ B_{WZ} & B_{WW} \end{bmatrix} \begin{bmatrix} Z_{t-1} \\ W_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ C_W \end{bmatrix} + \begin{bmatrix} Z_t \\ \tilde{u_t} \end{bmatrix} \tag{20}$$

Similarly, W_t includes the same set of economic variables. Now there are seven dependent variables on the left side. By restricting coefficients on Z_{t-p} to zero, we assume QE factor to be i.i.d and error terms follow

$$\begin{bmatrix} Z_t \\ \tilde{u_t} \end{bmatrix} \sim N(0, \Sigma) \tag{21}$$

That is, other variables will not affect QE factor while QE factor will have effects on others.

3.3 Local projection

LP-IV (Jordà, 2005) approach estimates the impulse responses to the shock using a two-stage least squares version of LP. It provides another convenient way to analyze the impulse response of long-term inflation expectations. Plagborg-Møller and Wolf (2021) show that LPs and VARs estimate the same impulse response which will agree approximately at short horizons (Proposition 2) and LP-IV impulse responses can equivalently be estimated from a recursive VAR that orders the IV first. To both test the argument and further analyze our research problem, we implement the following LPIV method. Consider the following recursive system:

$$y_{t+h} = c_h + \beta_h Z_t + \sum_{l=1}^{4} \phi_{1,h,l} X_{t-l} + \epsilon_{1,t+h} \tag{22}$$

$$\hat{u_t}^p = d + \gamma Z_t + \sum_{l=1}^{4} \phi_{2,l} X_{t-l} + \epsilon_{2,t} \tag{23}$$

$$\beta_{LPIV,h} = \beta_h / \gamma \tag{24}$$

where y_{t+h} is the h period ahead inflation expectation, Z_t is QE factor, X_t includes lagged value of the same set of economic variables in VAR. The impulse response of inflation expectation h period ahead can be directly estimated by taking the two-stage estimations.

4 Estimation

4.1 Data

For the high-frequency identification part, I collect the closing price of federal funds futures contracts that expire in the month of current FOMC meeting and next FOMC meeting, and eurodollar futures contracts that will mature 3,4,5 quarters after each FOMC meeting, ranging from 1990 February to 2022 March, in total 276 meetings. All of these can be attained in Bloomberg. Since FOMC meeting is held every 6 months and inflation expectation is released every month, the month without FOMC meeting is extrapolated as a simple average between the two most adjacent months with FOMC meeting.

For the VAR part, Inflation expectation data comes from Michigan Consumer Survey where long-term inflation means 5-year forward expectation and short-term inflation means 1-year forward expectation. The trends of inflation expectations are plotted in figure 3. I use long-term inflation expectations in the 25,50,75 percentile and short-term inflation expectations in the 25,50,75 percentile. Each quantile presents consumers' different attitudes toward the future. The treasury yields, inflation rate, unemployment rate, and Industry production index come from Federal Reserve Economic Data. The VAR estimation sample covers the same period from 1990 February to 2022 March while there are in total 386 monthly observations for each variable. Table 1 presents detailed summary statistics of variables used in further VAR estimation.

4.2 QE factors

Figure 2 shows estimated factors for the federal funds rate, forward guidance and QE, divided into two periods.

Table 1: Summary statistics of variables

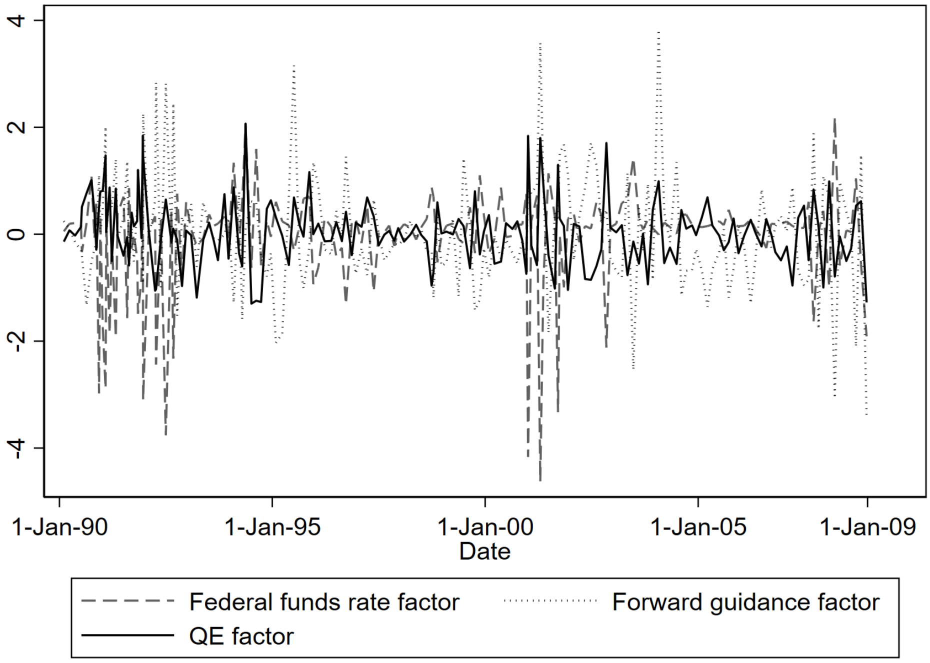
Variable	Obs	Mean	Std.Dev.	Min	Max
Longex_25	386	1.657	0.311	1.100	2.600
Longex_50	386	2.976	0.448	2.200	4.700
Longex_75	386	4.601	0.648	3.300	6.800
Shortex_25	386	1.202	0.665	-0.400	3.300
Shortex_50	386	3.011	0.613	0.400	5.400
Shortex_75	386	5.156	1.010	3.100	10.300
Treasury yields	386	3.731	2.225	0.220	9.080
Inflation	386	0.211	0.271	-1.771	1.377
Unemploy	386	5.882	1.722	1.722	14.700
Indusry production	386	90.604	13.389	59.783	108.261

Note: Table 1 presents summary statistics of variables used in the estimations. Longex variables denote 25% percentile, 50% percentile and 75% percentile of long-term inflation expectations, respectively. Shortex variables denote 25% percentile, 50% percentile and 75% percentile of short-term inflation expectations, respectively. Both are collected from Michigan survey data. The data is in the monthly frequency rom Feb 1990 to Mar 2022.

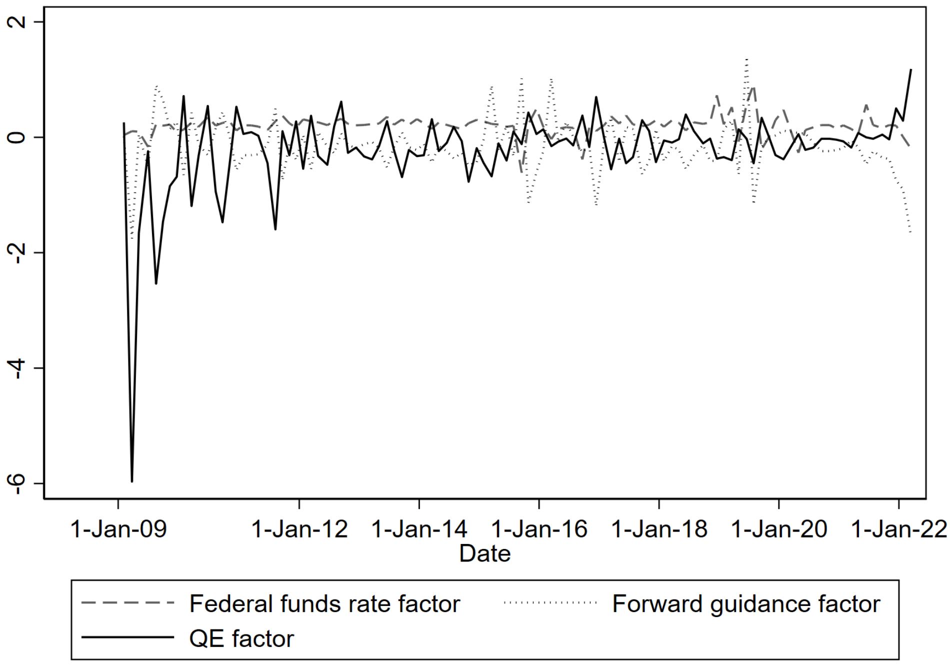
Figure 2(a) plots values from Feb 1990 to Dec 2008, covering the period when federal funds rate has not reached its zero lower bounds. It can be found that QE factor has the lowest variance among the three factors and is very close to zero which is expected under our assumption. It does not exactly equal to zero as Swanson (2021) says FOMC announcements may have implications for open market operations.

Figure 2(b) presents trends from Jan 2009 to the recent date, including the recovery period and covid period. A huge difference can be found here compared with figure 2. Firstly, the changes in the federal funds rate factor are slight during 2009-2015 and are very close to zero, which is consistent with the fact that the federal funds rate has reached zero lower bound and there is little space for the central bank to operate. It starts to fluctuate after 2018 but the size is still small compared with the other two factors. In this period, changes in the federal funds rate are the least important instrument. Comparatively, QE factor accounts for most of the variations in this period. It is remarkable that there is a

Figure 2: Identified monetary policy factors



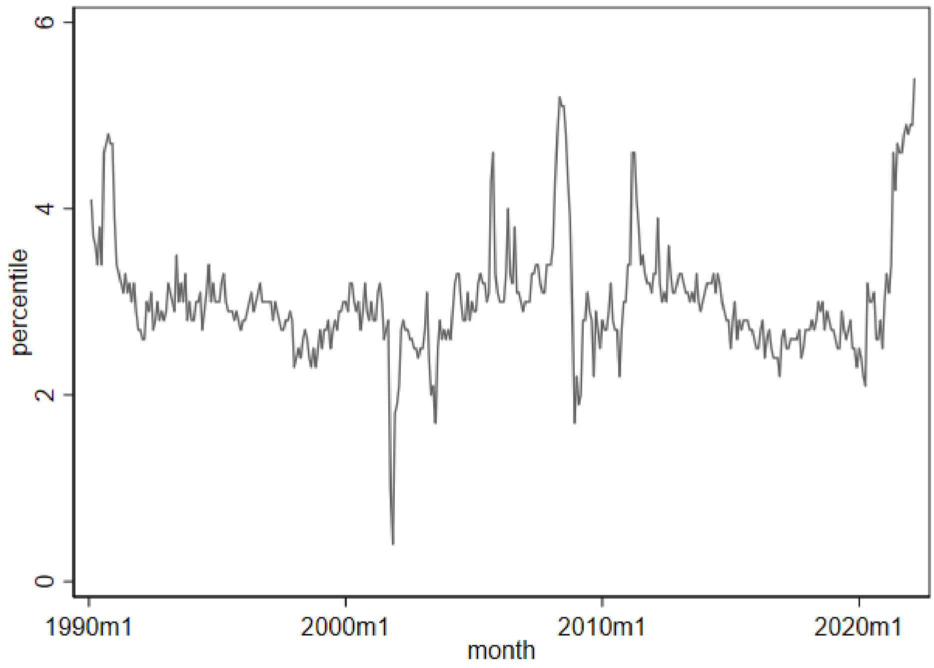
(a) Before QE



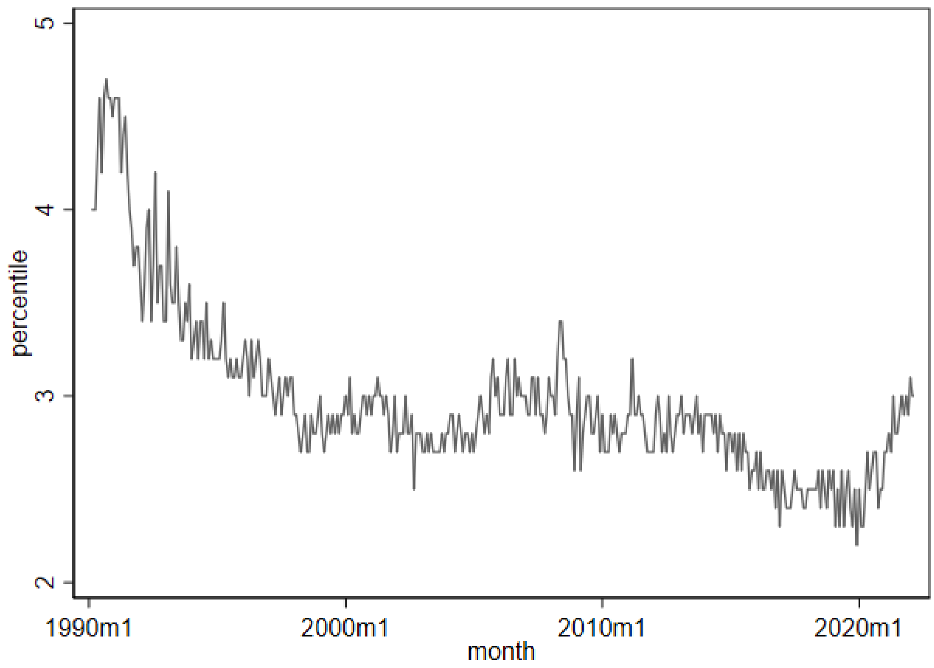
(b) After QE

Note: Figire 2 plots estimated factors for federal funds rate, forward guidance and QE from Feb 1990 to Mar 2022.

Figure 3: Identified monetary policy factors



(a) short-term inflation expectations



(b) long-term inflation expectations

sharp cut in Mar 2009 when FOMC announced an extension of QE1 purchase. It is obvious that QE1 did a really good job in lowering markets' expectations of future interest rates. The further QE2 in 2010 and QE3 in 2012 also lead to significant negative effects but sizes are much smaller than QE1 when not many agents can expect such an unconventional policy. After that, QE factor backs to the previous level and varies slightly around zero. Another special point is the latest point in Mar 2022 when FOMC announced to roll off its balance sheet which is called quantitative tightening. We can find that QE factor significantly increases to a high level. In other words, an increase in federate funds rate is expected by investors now.

4.3 Bootstrap

Following Mertens and Ravn (2013), confidence intervals for VAR with external instrument model are constructed using wild bootstrap under heteroskedasticity and strong instruments. Normal methods for confidence bonds does not work because of the external instrument used here.

First to get bootstrap QE factor $\tilde{F}^{(i)}$, we have $X = F\Lambda + \epsilon$. I randomly draw $\epsilon^{(i)}$ from the original sample with replacement and repeat 3000 times. Then generate bootstrap sample $X^{(i)} = F\Lambda + \epsilon^{(i)}$. For each bootstrap sample, I identify the bootstrap QE factor $\tilde{F}^{(i)}$ following the same procedure as before.

Then for the model:

$$W_t = \sum_{j=1}^{p} B_j W_{t-j} + u_t,\ u_t = S\epsilon_t \tag{25}$$

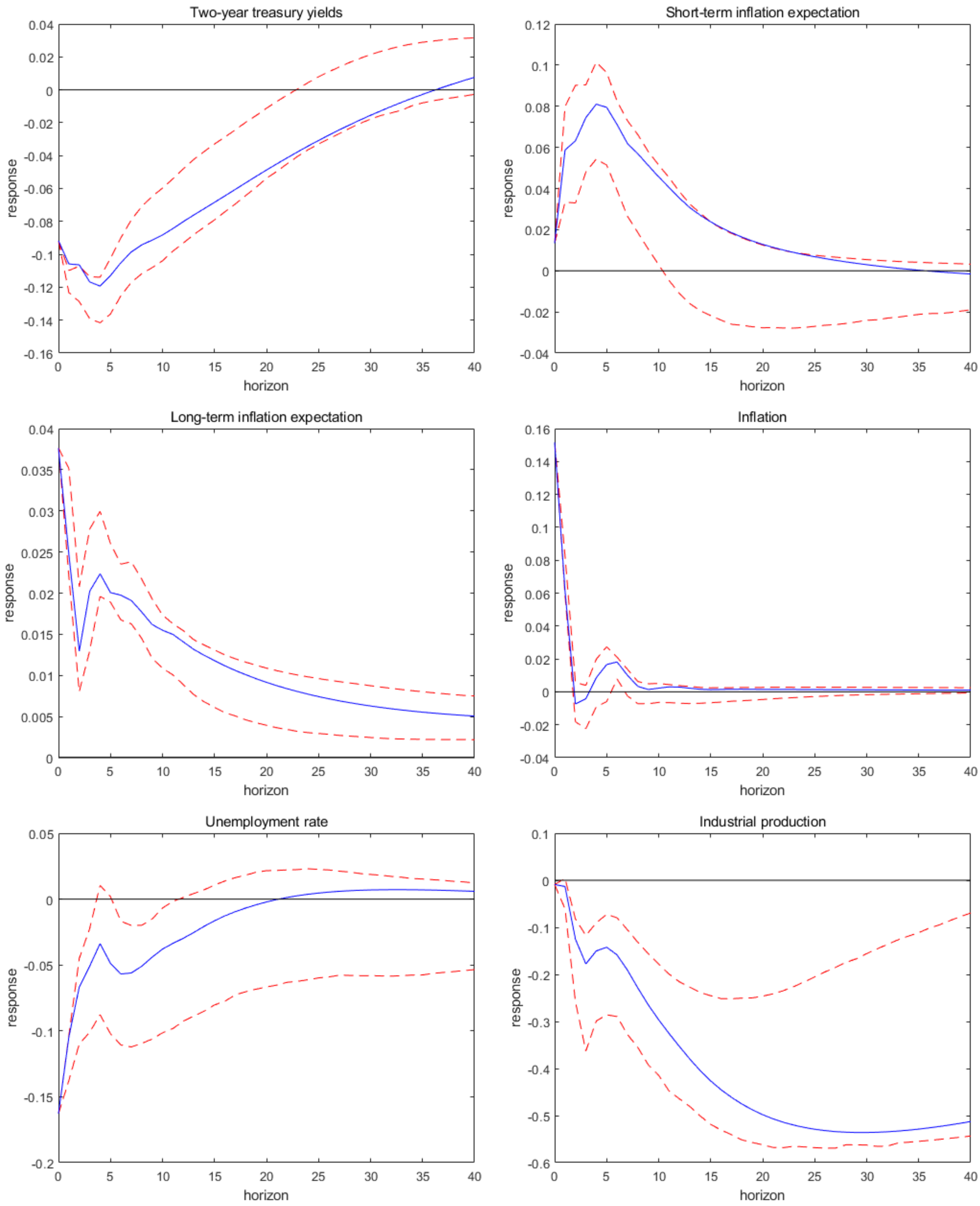
$$E[u_t u_t'] = SS' = \Sigma \tag{26}$$

$$u_t = (u_t^p, u_t^q)',\ \epsilon_t = (\epsilon_t^p, \epsilon_t^q)' \tag{27}$$

$$\tilde{u}_t^q = \frac{s^q}{s^p}\hat{u}_t^p + \zeta_t \tag{28}$$

we have original estimate $\hat{B}_j$ and $\frac{s^q}{s^p}$. With bootstrap QE factor $\tilde{F}^{(i)}$, we can generate

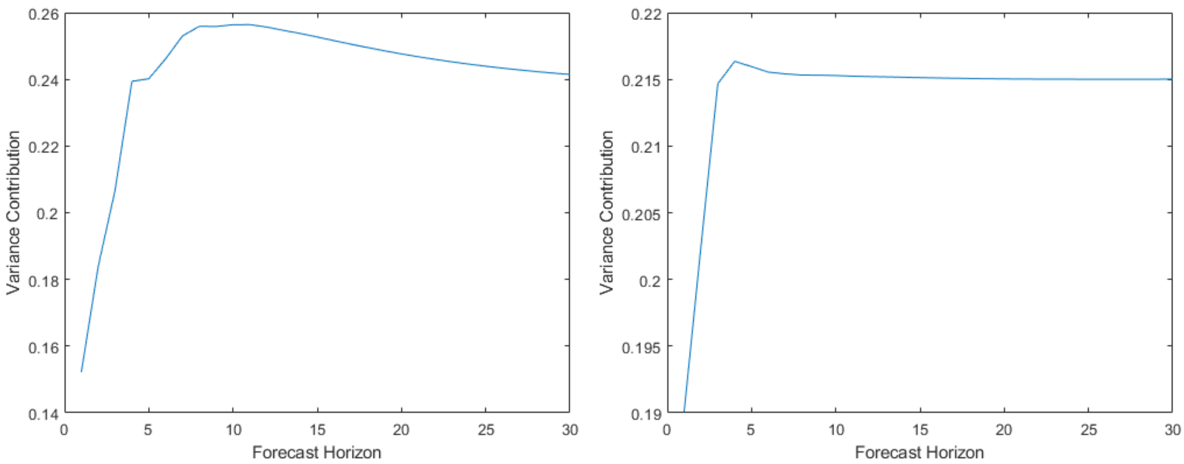
Figure 4: Impulse response for VAR with external instrument



Note: Figire 4 presents the impulse response of variables to the monetary policy shock using QE factor as external instruments. Red dotted lines are 90% confidence intervals constructed using wild bootstrap. Medium inflation expectations data is used. y-axis denotes percent change.

bootstrap $\hat{u}_t^{p(i)}$ since it is the fitted value from $\tilde{u}^p$ on original QE factor. Then we recover all fitted values $\tilde{u}_t^{q(i)}$. Thus with estimated coefficients $\hat{B}_j$, we can generate bootstrap

Figure 5: Variance decomposition for inflation expectations



(a) short-term inflation expectations (b) long-term inflation expectations

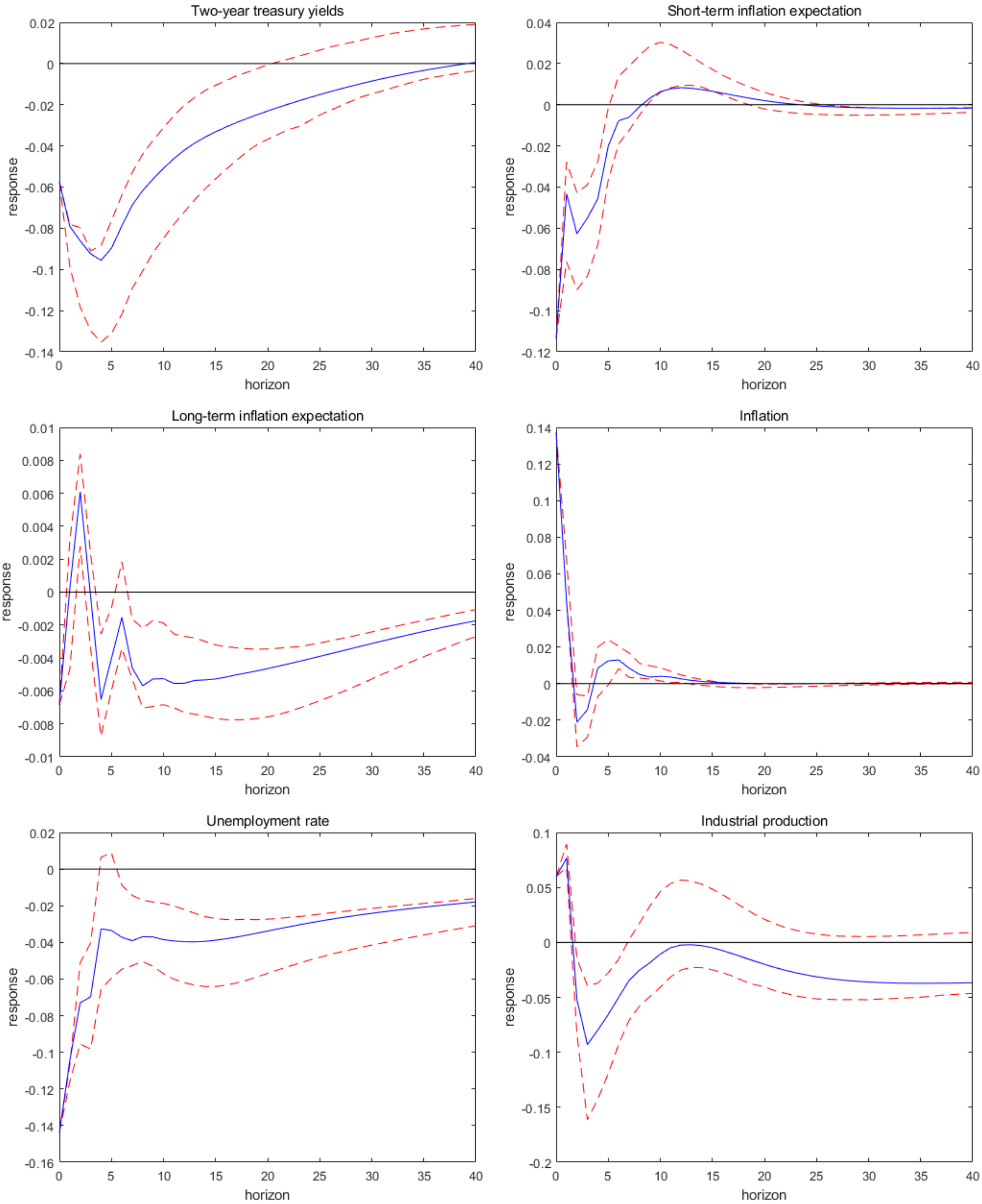
sample $W_t^{(i)}$ recursively. Then we can get the distribution of impulse response coefficients robust to conditional heteroskedasticity.

4.4 Impulse response to monetary shocks

Figure 4 draw the impulse response of VAR with external instruments model to QE shocks. It shows that one standard deviation of QE shock leads to a 0.01 percent change in long-term inflation expectations and around 21 percent variance of long-term inflation expectations is attributed to the QE shock.

In figure 4 I use median expectation data for short-term and long-term inflation expectations. Red dotted lines are 90% confidence intervals constructed using Bootstrap. We can see that both inflation expectations increase immediately after the QE shock, 0.06 percent for the short-term and 0.04 for the long-term. While short-term inflation expectations have a larger increase than long-term, it also decreases faster and the effect vanishes in the long term. In contrast, after a sharp immediate increase in the current period, long-term inflation expectations tend to suffer a consistent effect that at least last for a long time. That is, the surprising QE shock will make the public not only expect a

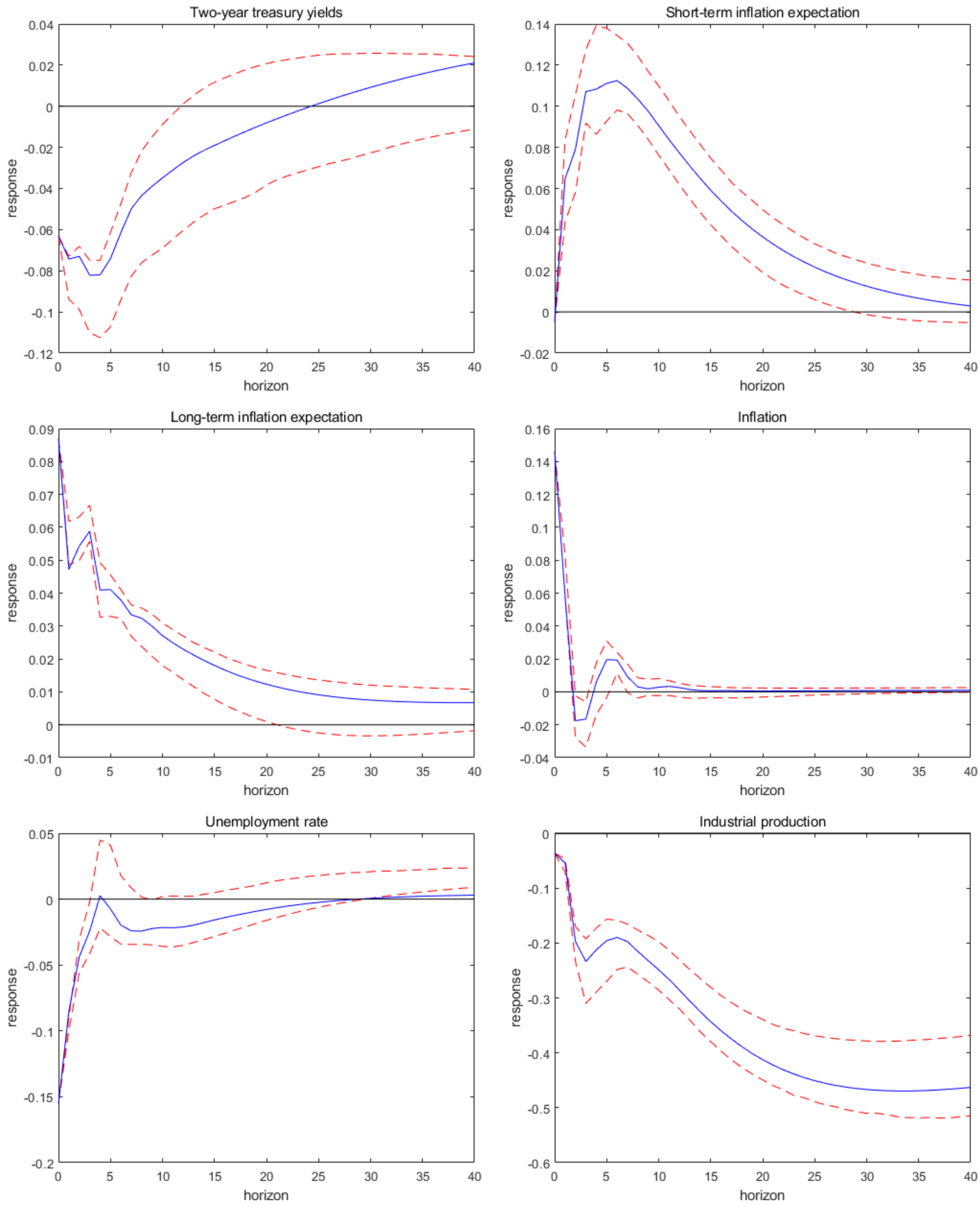
Figure 6: Impulse response with lower quantile



Note: Figire 6 presents the impulse response of variables to the monetary policy shock using QE factor as external instruments. Red dotted lines are 90% confidence intervals constructed using wild bootstrap. Inflation expectations at the lower quantile are used. y-axis denotes percent change.

current increase in inflation but also further worry about the future price increase and lead to a significant decrease in the market's confidence. Figure 5 presents the results of variance

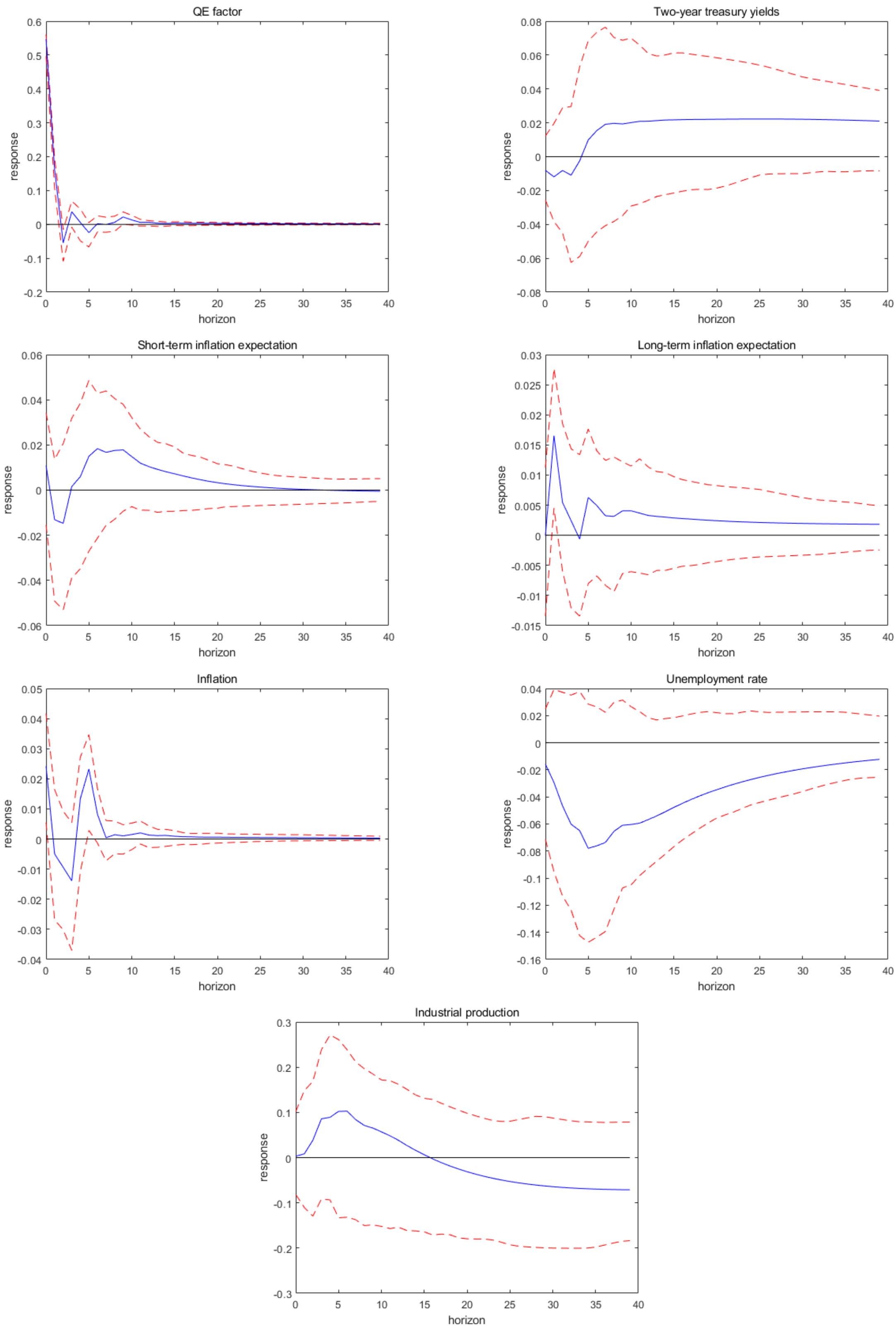
Figure 7: Impulse response with upper quantile



Note: Figire 7 presents the impulse response of variables to the monetary policy shock using QE factor as external instruments. Red dotted lines are 90% confidence intervals constructed using wild Bootstrap. Inflation expectations at the upper quantile are used. y-axis denotes percent change.

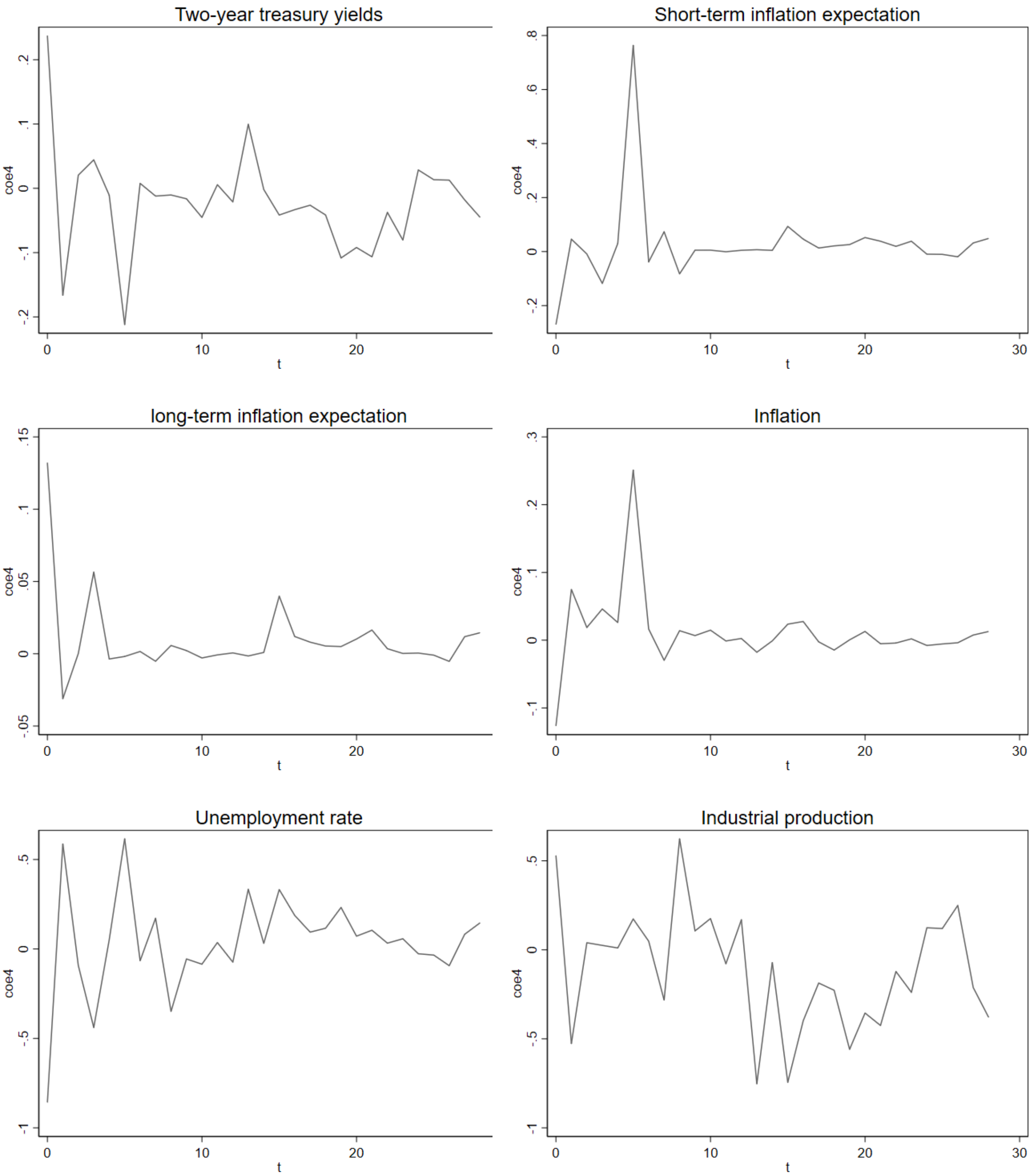
decomposition for inflation expectations. The QE shock is responsible for 24 percent of the variance in short-term expectations and 21 percent in long-term expectations. For

Figure 8: Impulse response of restricted VAR model



Note: Figire 8 presents the impulse response of variables to the monetary policy shock putting QE factor as a variable in the restricted VAR model. Red dotted lines are 90% confidence intervals constructed using Monte Carlo simulation. Inflation expectations at the medium are used. y-axis denotes percent change.

Figure 9: Local projection



Note: Figire 9 plots estimated coefficients using QE factor as the instrument in the local projection IV model.

other variables, the temporary rise in the inflation rate is expected and it returns to zero in the short period. The pattern in the unemployment rate and Industrial production is a bit confusing. It seems that a positive monetary policy will cause a recession in economic growth. But the result may be caused by the information effect that the Fed made the QE decision when they predict the occurrence of recession, making the QE shock negatively related to economic growth. Details are discussed in the later section.

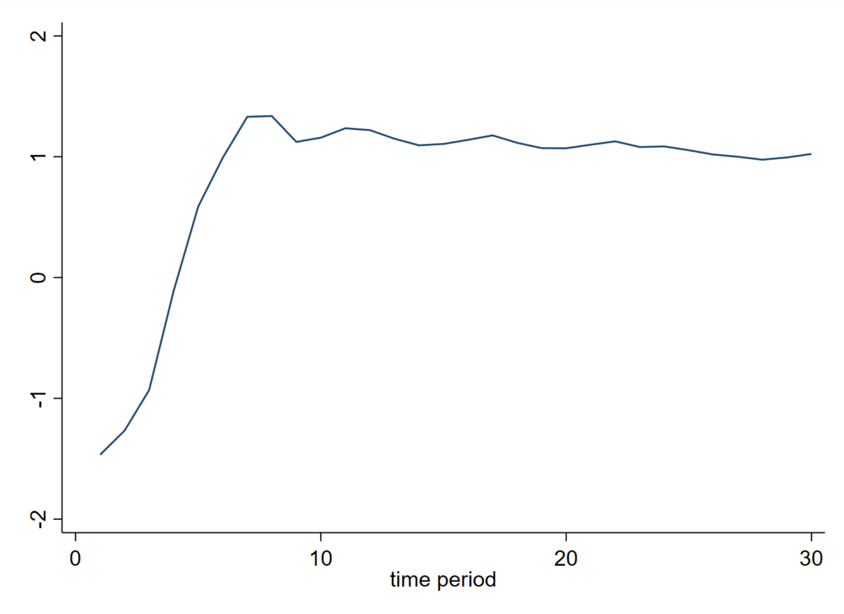
In figure 6 and figure 7 I replace median expectation data with lower quantile and upper quantile inflation expectations. The overall trend is similar to what we get from median data though there are some slight differences.

We can see that QE policy announcements have almost zero effects on both short-term and long-term expectations for optimistic agents with lower quantile expectations. And the effect of monetary policy to economic activity is minimized if the society is filled with optimistic agents. On the contrary, for pessimistic people, the effect of QE policy is amplified. Short-term inflation expectations have an extreme increase while effects on long-term inflation expectations are still persistent and larger. Also, economic growth is affected more heavily.

Figure 8 presents results for the restricted VAR model where QE factor is directly put in the regressors. The confidence interval is constructed using Monte Carlo simulation. It is certain that the overall trends of impulse response are almost the same as what we get in the previous model. The effect of monetary policy shock is transitory for short-term inflation expectations while permanent for long-term. While the size of the effects is a little smaller compared with the previous one and the variance is larger. It is notable that QE factor goes back to zero just one period after the shock which is evidence of independence.

And figure 9 are two-way line figures for the LPIV model with coefficients on the y-axis and forward period on the x-axis. In general, results are consistent with the arguments that LPIV results are the same as estimations from a recursive VAR which orders the

Figure 10: Information effect test



Note: Figire 10 plots the sequence of estimated coefficients by regressing future GDP growth on the current QE factor .

IV first. Comparing figure 5 and 6, the trends are similar while the impulse response in figure 5 is smoother and has a smaller size. The conclusion is similar to before: both coefficients on long-term and short-term expectations are close to zero after a long period while long-term expectations fluctuate more.

5 Information effect

There are some potential issues of High-frequency identification since the Fed may have a larger information set than the public. Bauer and Swanson (2022) also points out the problem and tries to address them by expanding the set of monetary policy announcements to include speeches by the Fed Chair and further orthogonalizing the surprises with financial data before the FOMC announcement.

Here I analyze the information effects by regressing future GDP growth on the current QE factor and get a sequence of estimations to test the predictive power of the monetary policy factor

$$g_{t+k} = c_k + \beta_k Z_t + \epsilon_{t+h} \tag{29}$$

$$g_{t+k} = 100(12/k)(ln(IP_{t+k}) - ln(IP_t)) \tag{30}$$

where IP_t is the industrial production index and Z_t is the monetary policy indicator.

The results in figure 10 show that the estimated coefficient is negative for the first 5 monthly periods and increases to a constant level of 1 after 10 periods. We can think that when QE announcement is made, the economic activity level is going to decline and the Fed predicts the recession therefore they made the QE decision. Then after several time periods, the monetary policy takes effect and the economy starts to recover.

Our results are consistent with some empirical evidence. For example, Campbell et al. (2017) found the information channel that expansionary monetary policy surprises are associated with upward revisions in unemployment rate survey forecasts. Our results can also be viewed as a piece of evidence that the Fed has more information and thus higher prediction power.

6 Conclusion

This paper empirically analyzes the effects of QE shock on US long-term inflation expectations. I use high-frequency data from the financial market and exploit price changes of federal funds futures and eurodollar futures before and after each FOMC meeting to identify QE factors attributing to price variation. Then I estimate the effects of monetary policy shock to survey-based inflation expectations using the QE factor as an external instrument in the VAR model and test with a corresponding LP-IV model.

The estimation results provide similar conclusions in all models. One of the key findings is that upon observing the QE shock, it is evident that both short-term and long-term inflation expectations rise instantly. Short-term inflation expectations exhibit a more substantial increase compared to long-term expectations; however, they also decline more rapidly, and their impact diminishes over time. Conversely, long-term inflation expectations experience a sharp initial increase in the current period and maintain a persistent effect for an extended duration.

The results indicate that an unexpected QE shock not only causes the public to anticipate an immediate surge in inflation but also heightens concerns about future price increases, resulting in a considerable decline in the market's confidence in the Fed and leading to potential inflation expectation unanchoring.

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