Measuring Information Effects of Monetary Policy: New Evidence from the VIX Futures Market*

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VERY PRELIMINARY AND INCOMPLETE

Abstract

I provide new evidence on the information content of monetary policy announcements. I construct shocks from 30-minute changes in VIX futures prices around FOMC announcements which are orthogonal to traditional high-frequency monetary policy shocks. I find that changes in the VIX futures are well represented by a level and slope factor. After purging them from variation due to changes in the yield curve, I find that an increase in the level factor leads to a significant contraction in economic activity, whereas the increase in slope factor does not lead to sizeable effects. My findings emphasize the effect of monetary policy releases on real economic activity through its information release, and beyond their impact on the yield curve.

JEL Codes: E44, E52, G13

Keywords: Monetary Policy, Information Effects, VIX, Futures, Uncertainty

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1 Introduction

The importance of monetary policy communication, so called forward guidance, has increased starkly over the last 30 years, and has become a central part of many central banks' toolkit around the world. Hand in hand with this development, a large literature has emerged trying to understand the transmission of forward guidance policies to the economy.

Despite a voluminous literature by now, there is still substantial disagreement over the transmission channels of forward guidance. In particular, information effects, i.e. the effects a monetary policy announcement has through its release of news about the macroeconomy, are still under debate.[1] Whereas multiple papers emphasize the importance of them (Nakamura and Steinsson, 2018; Jarociński and Karadi, 2020), other argue that they do not play an important role (Bundick and Smith, Forthcoming; Bauer and Swanson, 2020). So far, the literature mostly focuses on the information effects through its impact on the term structure of interest rates. However, there is no particular reason why FOMC announcements cannot provide information on macroeconomic behavior which does not directly show up in the yield curve.

In this paper, I propose a new way of measuring information effects of monetary policy by constructing shocks from 30-minute changes in VIX futures prices around FOMC announcements which are orthogonal to traditional monetary policy shocks. The use of VIX futures is motivated by two observations. First, as prior work shows the VIX is a highly informative indicator for economic activity.[2] The VIX measures economic uncertainty (Bloom, 2009), as well risk aversion (Carr and Wu, 2009). It is also a powerful predictor of global financial markets (Rey, 2013). Second, the VIX futures market is a rapidly growing market which allows financial participants to trade in real-time on the expected path of the VIX (Mixon and Onur, 2015). Hence, VIX futures are highly liquid asset prices allowing one to measure surprises to agents' information sets by studying their changes in a tight window around news releases.

The construction of the shocks follows in two steps. First, I calculate 30-minute changes of VIX futures around FOMC releases. The underlying identification assumption is that these changes are driven by FOMC announcements. I focus on the first 8 contracts covering the expected path of the VIX over the next 8 months. Following previous methodology, I show that these changes are indeed systematic, i.e. VIX futures changes contain helpful

[1] Other names for information effects are Odyessean forward guidance (Campbell et al., 2012), or signaling effects (Melosi, 2017).

[2] The VIX is the 30-day option-implied volatility index of the S&P 500 index.

information about the monetary policy releases, and that they are well described by two factors. Using principal components, I show that these two factors can be interpreted as a level and slope factor. The former leading to an upward shift in the entire VIX futures curve, whereas the latter increases contracts with less than 4 months of maturity and decreases contracts with more than 4 months of maturity.

At this point, these factors are potentially containing redundant information with respect to conventional estimated shocks from interest rates futures. Hence, I regress both factors on surprises of the entire yield curve, i.e. 30-minute changes in Federal Funds rate, Eurodollar, and Treasury futures following the previous literature. The residuals of both regressions are the information shocks of interest. Traditional monetary policy shocks can explain around 40% of the variation of the VIX level factor and 14% of the VIX slope factor.

Lastly, I aggregate both series to a monthly frequency and employ a Jordà (2005) local projection to study if both shock series have a potential effect on economic activity. Indeed, the VIX level shock shows a rise in the VIX, a fall in prices, as well as real economic activity. Importantly, it does not move the short-term nominal rate, and moves the 10-year nominal rate slight downward. Importantly, shock does not look like any monetary policy shock transmitting through the yield curve. The results for the VIX slope shock are a more noisy and harder to interpret. Most economic variables do not show significant responses.

Related Literature My paper relates to various strands in the literature. First, this paper is related to a large body of work studying the effects of monetary policy by looking at FOMC announcements (Kuttner, 2001; Bernanke and Kuttner, 2005; Gürkaynak, Sack, and Swanson, 2005; Campbell et al., 2012; Del Negro, Giannoni, and Patterson, 2012; Hanson and Stein, 2015; Swanson, 2017; Nakamura and Steinsson, 2018). More precisely, my paper relates to a growing literature focusing on different types of forward guidance. In particular, my paper relates to work going beyond high-frequency yield curve movements to assess different kinds of forward guidance communications. For example, Cieslak and Schrimpf (2019) and Jarociński and Karadi (2020) employ the joint reaction of the yield curve and the stock market around FOMC announcements to differentiate between different communication strategies. Andrade and Ferroni (2020) employ changes in yield curve and inflation swaps. Similar to these papers, I argue that the yield curve reaction to monetary policy news is not a sufficient statistic to assess monetary policy. My contribution here is to show that monetary policy communication can affect the macroeconomy beyond movements in the yield curve.

Second, my paper refers to growing literature which tries to study VIX futures. Park (2015) provides evidence that VIX futures prices are potentially leading S&P 500 options which underlie the VIX. Multiple papers study the relationship between the term structure of VIX futures and the variance risk premium (Johnson, 2017; Cheng, 2019). Closest to my paper is-Fernandez-Perez, Frijns, and Tourani-Rad (2017) who study information incorporation of FOMC announcements in VIX futures prices. They find that VIX futures are not responding instantaneously as other asset prices do. As I show below, VIX futures seem to incorporate the FOMC release almost immediately after an announcement. This difference in findings is potentially due to the low liquidity of VIX futures in the first years after their creation in 2004. Whereas Fernandez-Perez, Frijns, and Tourani-Rad (2017) focus on a sample from 2004 to 2013, my sample ranges from 2010 to 2020.

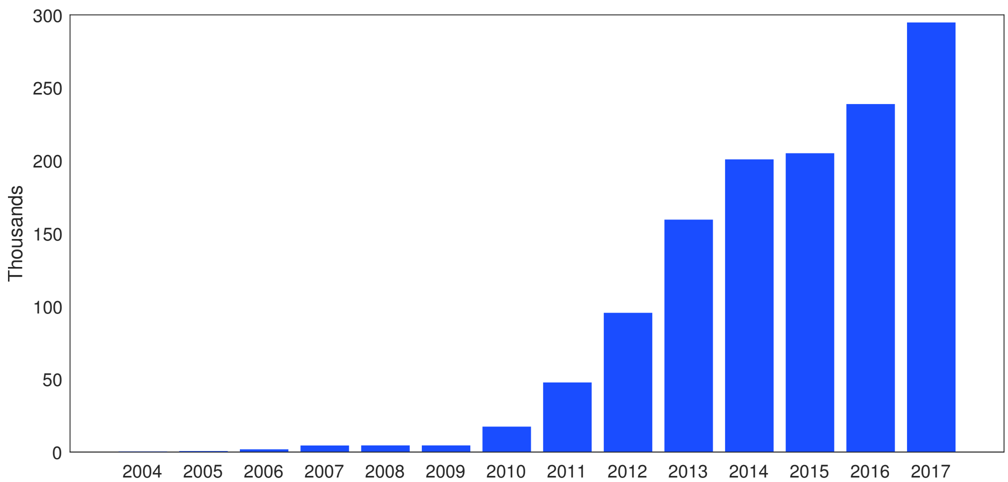
Third, my paper refers to a recent monetary policy literature which tries to capture "second-moment" monetary policy shocks. Bundick, Herriford, and Smith (2017) and Bauer, Lakdawala, and Mueller (2019) calculate daily measures of interest rate uncertainty based on Eurodollar options. Compared to these papers, I focus not on uncertainty of interest rates but uncertainty of the stock market, and hence try to capture a more direct measure of the effect of the monetary policy release on the macroeconomy. Further, the use of VIX futures allows me to employ intraday data which is often found to be helpful in the event-study literature to precisely measure the effects of a particular event (Gürkaynak, Sack, and Swanson, 2005; Rigobon and Sack, 2008). That being said, I find similar to Bundick, Herriford, and Smith (2017) that monetary policy can affect macroeconomic outcome through its effect on second moments.

Roadmap The remainder of the paper is structured as follows. Section 2 provides information on the VIX futures market and other data employed in the paper. Section 3 details the construction of the shocks. Section 4 studies the macroeconomic effects of the shock series. Section 5 concludes.

2 Background and Data

The literature review above makes clear how the VIX is a highly informative indicator for domestic and global financial activity. The research interest in the VIX is also shared by financial market participants. Since the Chicago Board Options Exchange (CBOE), who is also responsible for the VIX, introduces VIX futures in 2004, they become extraordinary popular. Figure 1 shows how the trading volume has substantially increased over the years. Since the VIX is an index, i.e. non-tradable, VIX futures provide financial participants an easy way to trade in the VIX.

Figure 1: VIX Futures Market—Average Daily Trading Volume



Notes: This figure plots the average daily trading volume of VIX futures per year from 2004 to 2017. Source: *CBOE*.

A VIX futures (VX) contract pays out based on the VIX's value on the date of expiration. Hence, the contract's price reflects the market participants' expectation of the value of the VIX on the expiration date. At any given point in time, VIX futures with different maturities are traded. Let $VX^{(h)}$ be the VX futures price with horizon h. Then the expiration date is between $h-1$ and h months at any given point in time. Based on these prices one can construct a VIX futures term structure. Importantly, this is different to the VIX term structure which reports the implied volatility for different maturities.

I employ intrady data on asset prices form *Thomson Reuters Tick History* and obtained from *Refinitiv*. Table 1 provides an overview of intraday data used throughout the paper. Although the first VX futures contracts start trading in 2004, I begin my sample in 2010 due to relatively low trading volume in the first years and the financial crisis. I end the sample in January 2020 prior to the Coronavirus recession. I focus on the first 8 contracts, i.e. $\text{VX}^{(h)}$ for $h = 1, \ldots 8$, due to data availability.

To construct surprises in the yield curve, I also employ Federal Funds Rate, Eurodollar, and Treasury Futures as commonly done in the literature.[3] These choices are based on a

[3]Treasury futures close in March, June, September, and December. Following Gorodnichenko and Ray (2017), I focus on the closest contract except in the month of expiration in which case I employ the next contract. The reason

large literature constructing monetary policy surprises from interest rate futures (Kuttner, 2001; Gürkaynak, Sack, and Swanson, 2005).

Table 1: Overview of Intraday Financial Data

Name	Symbols	RICs	Sample
VIX Futures first 8 contracts (monthly)	$VX^{(1)}$–$VX^{(8)}$	VXc1–VXc8	1/2009–1/2020
Federal Funds Rate Futures first 4 contracts (monthly)	FF1–FF4	FFc1–FFc4	1/2009–1/2020
Eurodollar Futures first and fourth contract (quarterly)	ED1, ED4	EDcm1, EDcm4	1/2009–1/2020
2-Year Treasury Futures	TU	TUc1,TUc2	1/2009–1/2020
5-Year Treasury Futures	FV	FVc1,FVc2	1/2009–1/2020
10-Year Treasury Futures	TY	TYc1,TYc2	1/2009–1/2020
30-Year Treasury Futures	US	USc1,USc2	1/2009–1/2020

Notes: This table provides an overview of the intraday data from *Thomson Reuters Tick History*. *Symbol* stands for the ticker symbol which I use throughout the paper to refer to the financial instrument. *RIC* refers to the Reuters Instrument Code, which uniquely identifies each instrument. The letters *c* and *cm* stand for continuous futures contracts.

I obtain dates and times of the FOMC press releases from Bloomberg. I also cross-check them with information from the Federal Reserve website,[4] and data from Jarociński and Karadi (2020). All FOMC announcements over my sample period are scheduled. Following Campbell et al. (2012), I exclude the QE1 announcement on March 18, 2009. This gives me in total 89 announcements over the sample period.

3 Construction of The Shocks

In this section, I lay out the construction of the shock series which is done in two steps. In the first one, I measure surprises in the VIX term structure by constructing price changes in VIX futures contracts in a 30-min window around FOMC announcements. The underlying identification assumption is that 30-changes in VIX futures prices reflect unexpected changes in the VIX term structure from news about monetary policy. In the second step, I regress on which by regressing the surprises in the VIX term surprises (and squared surprises) of the yield and the stock market. The resulting residuals are the shocks of interest. This

for this is that the closest contract has generally a lower trading volume in the month of expiration.

[4] https://www.federalreserve.gov/monetarypolicy/fomccalendars.htm.

decomposition makes sure that the variation can be interpreted as second-moment news, and not redundant information due to first-moment effects of the FOMC announcement.

3.1 Measuring Surprises in VIX Term Structure

Let $VX_{t,post}^{(h)}$, $VX_{t,post}^{(h)}$ be the VIX futures price with expiration h after and before the FOMC announcement t. The surprise $\Delta VX_t^{(h)}$ is then calculated as

$$\Delta \mathrm{VX}_t^{(h)} = 100 \times \left(\log \mathrm{VX}_{t,post}^{(h)} - \log \mathrm{VX}_{t,pre}^{(h)} \right),$$

where $\mathrm{VX}_{t,pre}^{(h)}$ is the last price observed 10 minutes before the announcement, and $\mathrm{VX}_{t,post}^{(h)}$ is calculated as the first price observed 20 minutes after the announcement

In order for the identification to work, two basic requirements are needed. First, the VIX futures responds to the FOMC announcements in a systematic, non-random fashion. Second, the futures prices incorporate the revealed information in a timely fashion. Those two points make sure that the 30-min changes are actually capturing what they intend to. A first check is to look at price movements around FOMC announcements. Figure 2 shows the intraday movements of the $\mathrm{VX}^{(1)}$, $\mathrm{VX}^{(4)}$, and $\mathrm{VX}^{(8)}$ around 3 selected FOMC press releases in my sample.

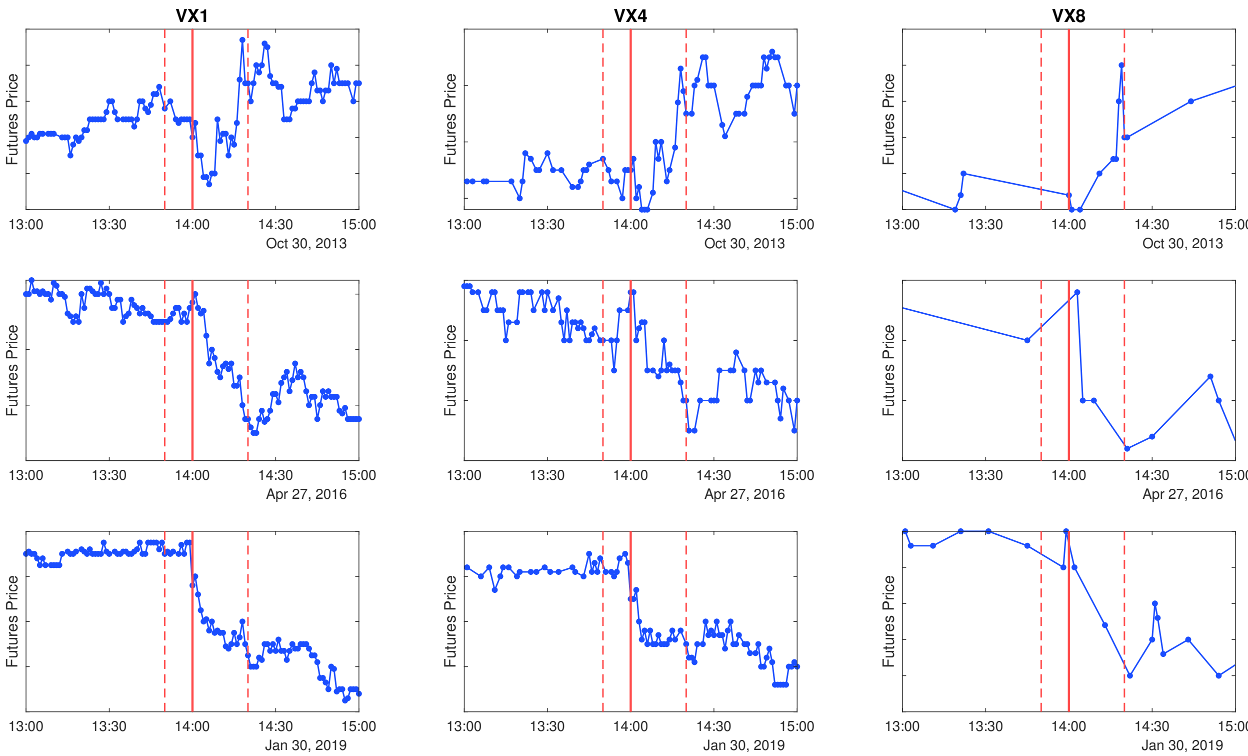
Figure 2 illustrates that VIX futures are responding in a systemic fashion to the FOMC release, i.e. they are informative about news released in the announcement. I now formally test this by using the factor methodology outlined in Gürkaynak, Sack, and Swanson (2005). Let X denote the $T \times n$ matrix of 30-minute changes in VIX futures where each row corresponds to a FOMC announcement and each column to a VIX futures contract, i.e. $T = 89$ and $n = 8$. Then the factor structure is given by

$$\underset{(T\times n)}{X} = \underset{(T\times k)}{F}\underset{(k\times n)}{\Lambda} + \underset{(T\times n)}{\varepsilon},$$

where F is a $T \times k$ matrix of common latent factors , Λ is the $T \times k$ matrix of factor loadings, and ε is the $T \times n$ matrix of idiosyncratic variation of VIX futures at each horizon. Using the matrix rank test of Cragg and Donald (1997), one can test how many factors k are needed to sufficiently describe the matrix X.

Table 2 reports the results of this exercise. First, the fact that $k = 0$ can be easily rejected, confirms that VIX futures are responding in a systematic fashion. Second, the results indicate that two factors are sufficient to describe the changes in the VIX futures term structure since $k = 2$ can be not rejected at the 5% significance level.

Figure 2: VIX Futures Prices around 3 Selected FOMC Annoncements



Notes: This figure shows the intraday movements of the 1-, 4-, and 8-month VIX futures contract around 3 selected FOMC announcements in the sample. The figure also displays the time of the release (solid vertical line), and the 30-minute window around the release (dashed vertical lines). The vertical axis is left unlabeled since the futures data is purchased from *Refinitiv*. Hence, I cannot release the raw futures prices.

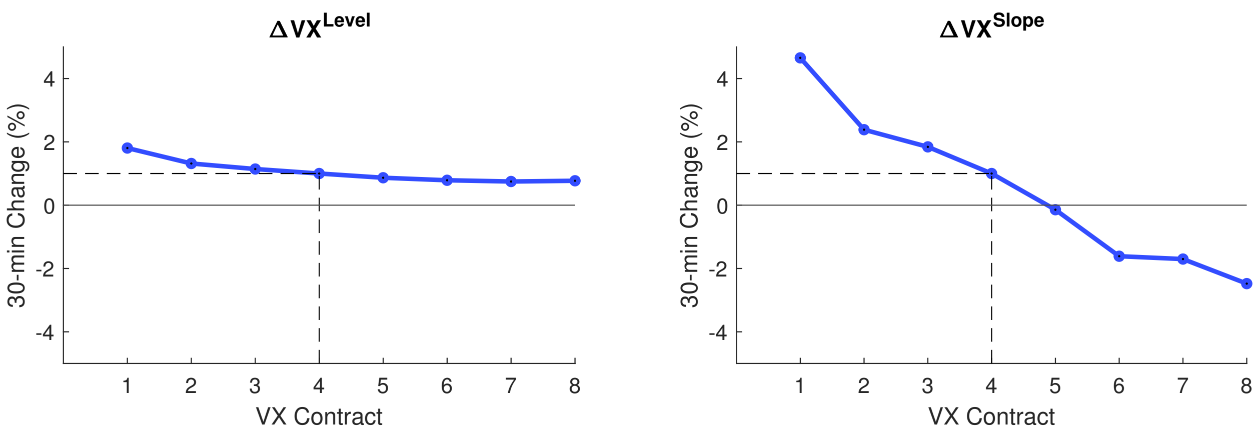
Table 2: Testing the Number of Factors Characterizing VIX Futures Changes

H_0: Number of Factors k_0	Wald Statistic	χ^2 Degrees of Freedom	p-value	Observations
$k_0 = 0$	154.76	28	0.000	89
$k_0 = 1$	60.67	20	0.000	89
$k_0 = 2$	21,79	13	0.059	89

Notes: This table shows the results of Cragg and Donald's (1997) rank tests of matrix X, where X includes the 30-minute changes of VIX futures around FOMC announcements from January 2009 to January 2020. Each row reports results for the mull hypotheses of $k = k_0$ against the alternative of $k > k_0$.

Based on these rank tests, I estimate two factors from the data matrix X using principal components. The resulting two orthogonal factors explain maximal fraction of the variation in X. Figure 3 shows the loadings of both factors on the changes in the VIX futures, where I normalize each factor such that it corresponds to 1-percent increase in $VX^{(4)}$. Although the estimated factors generally do not have a clean economic interpretation, they can be in this case interpreted as a level and slope factor. $\Delta\text{VX}^{\text{Level}}$ shifts the VIX futures curve equally upward, whereas $\Delta\text{VX}^{\text{Slope}}$ tilts VIX futures curve by increasing (decreasing) the prices of futures contract below (above) 5 months.

Figure 3: Factor Loadings



Notes: This figures shows the loadings of the factors $\Delta\text{VX}^{\text{Level}}$ and $\Delta\text{VX}^{\text{Slope}}$ on the 30-minute changes in the VIX futures term structure around FOMC meetings. The horizontal axis corresponds to the number of months until the VIX futures contract expires. The dotted line shows the factor normalization such that each factor corresponds to 1-percent increase in $VX^{(4)}$.

3.2 Decomposition

In the previous subsection, I show that the VIX futures market responds systematically, and multidimensional to monetary policy news. I will now assess how much of this information is due to news about interest rates, i.e. traditional monetary policy shocks, and how much is unexplained by it. To do so, I construct monetary policy surprises to the entire yield curve.

In particular, I construct the following decomposition

$$\Delta\text{VX}_t^j = \widehat{\Delta\text{VX}^j}_t + \varepsilon_t^j, \qquad \text{for } j = \{\text{Level, Slope}\}.$$

Here, $\widehat{\Delta\text{VX}^j}_t$ and ε_t^j are estimated as the fitted value and the residual from the following regression:

$$\Delta\text{VX}_t^j = \alpha_j + \beta_j X_t + \gamma_j X_t^2 + \varepsilon_t^j, \tag{1}$$

where vector X_t captures 30-min surprises in the yield curve, i.e.

$$X_t = [\text{MP1, MP2, }\Delta\text{ED1, }\Delta\text{ED4, }\Delta\text{TU, }\Delta\text{FV, }\Delta\text{TY, }\Delta\text{US}]'.$$

MP1 and MP2 capture surprises in the Federal Funds Rate over the next three months following the construction in Kuttner (2001) and Gürkaynak, Sack, and Swanson (2005). The other asset prices capture changes of the rest of the yield curve.[5] Further, X_t^2 refers to a vector containing the squared series of each element in X_t. They capture the fact that not only the direction but also the pure magnitude of the interest rate surprises affects volatility, and hence VIX futures prices.

Table 3 reports the R-squared of regression (1) for each factor. Traditional monetary policy shocks can explain up to 40% and 14% of the variation in $\Delta\text{VX}_t^{\text{Level}}$ and $\Delta\text{VX}_t^{\text{Slope}}$, respectively. This emphasizes two points. First, by looking at the yield curve, one is only capturing parts of the information release of the monetary policy announcement. Second, a large portion of the stock market is not explained by traditional monetary policy shocks consistent with prior research.

Table 3: R-squared Results of Equation (1)

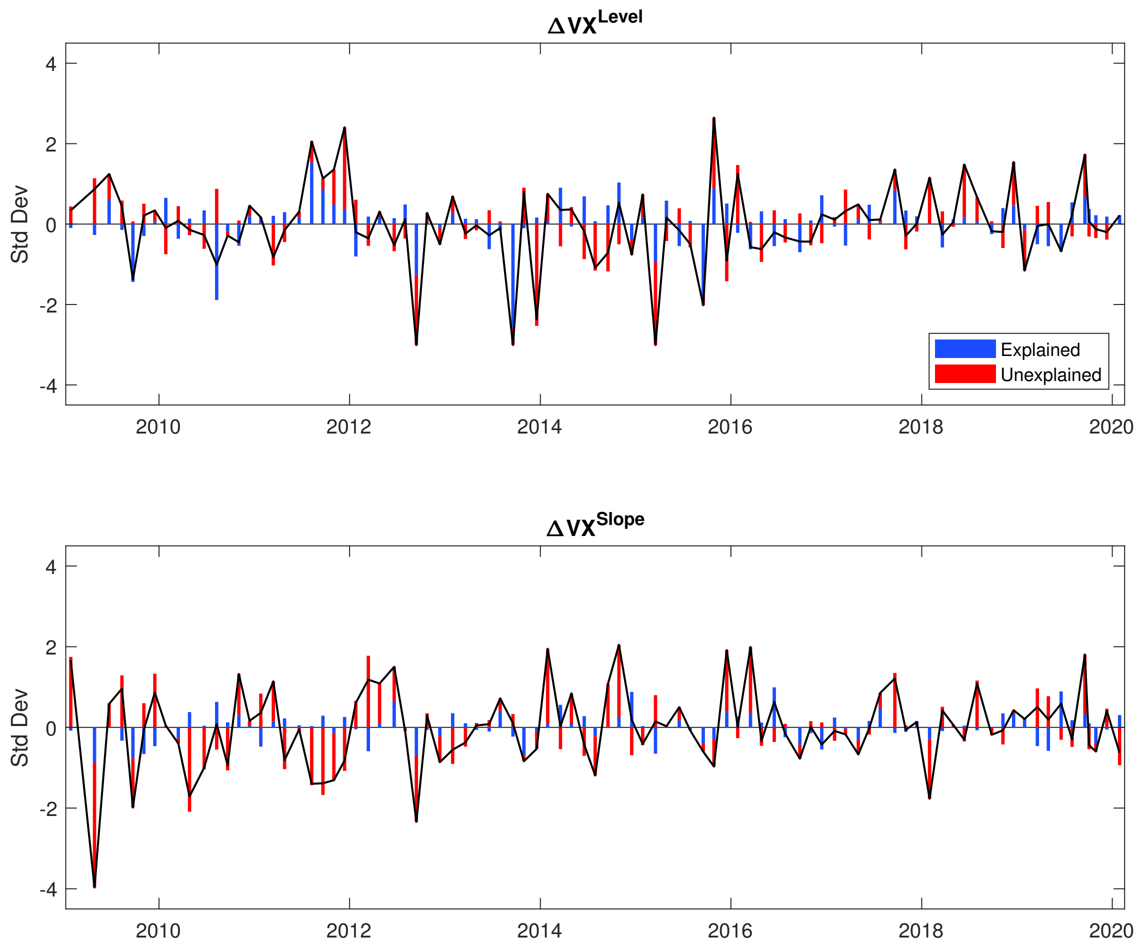
	$\Delta\text{VX}^{\text{Level}}$	$\Delta\text{VX}^{\text{Slope}}$
R^2	0.40	0.14
Observations	89	89

Notes: This figure shows the R^2 of regression (1) for both factors, $\Delta\text{VX}_t^{\text{Level}}$ and $\Delta\text{VX}_t^{\text{Slope}}$.

Figure 4 displays the time series of both factors, and their decomposition, i.e. ΔVX_t^j (black solid line), $\widehat{\Delta\text{VX}^j}_t$ (blue bars), and ε_t^j (red), for $j = \{\text{Level, Slope}\}$, over the sample period. Figure 4 visualizes the shares of explained and unexplained variation. It also makes clear that the results are not driven by one or two extreme announcements.

[5]Following Gürkaynak, Kısacıkoğlu, and Wright (2018), I convert all Treasury futures changes in yield changes by dividing them by their approximate duration and by flipping the sign. However, it does not really matter for the purpose of the decomposition.

Figure 4: Time Series of Factors and Their Decomposition



Notes: The figure shows the time series resulting from the estimated decomposition (1). For each $j = \{\text{Level, Slope}\}$, the figure shows the time series of the factor ΔVX_t^j (black solid line), the explained part $\widehat{\Delta \text{VX}^j}_t$ (blue bar), and the unexplained one (shock) ε_t^j (red bar).

4 The Macroeconomic Effects

The previous section shows that there is a substantial amount of unexplained variation in the VIX futures term structured which is captured by the two shocks $\varepsilon^{\text{Level}}$ and $\varepsilon^{\text{Slope}}$. I now assess the effect of both shock series on macroeconomic variables at a monthly frequency. To do so, I first aggregate each series to a monthly level by summing it up. I then estimate the following Jordà (2005) local projection:

$$x_{m+h} = \alpha_h + \beta_h \varepsilon_m^{\text{Level}} + \gamma_h \varepsilon_m^{\text{Slope}} + \sum_{k=1}^{12} \theta'_{h,k} W_{m-k} + \nu_{m+h},\ h = 1, .., 18, \tag{2}$$

where β_h and γ_h are the coefficents of interest capturing the dynamic effect of $\varepsilon_m^{\text{Level}}$ and $\varepsilon_m^{\text{Slope}}$ on outcome variable x at horizon h, respectively. The vector W denotes control variables and is given by

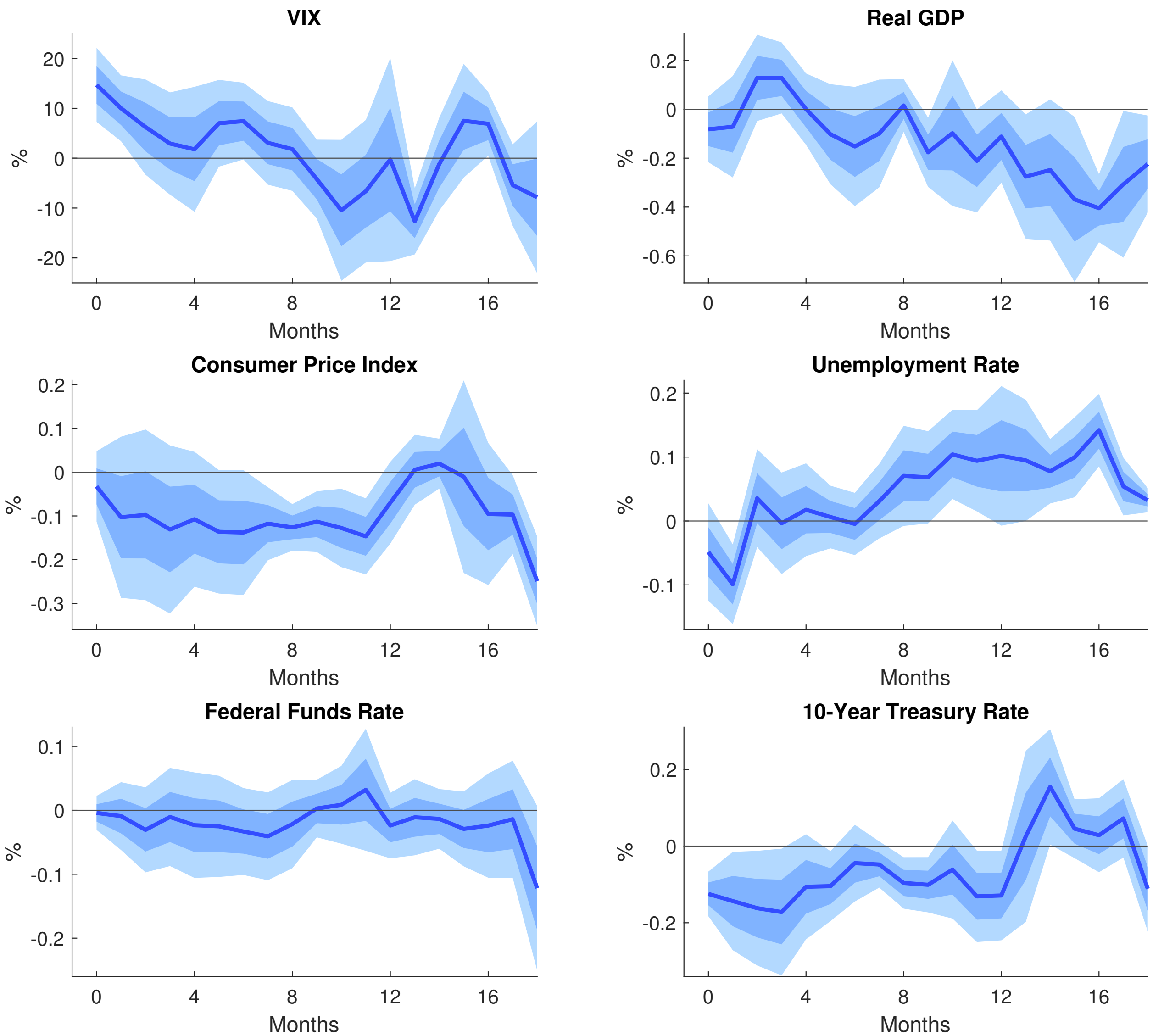
$$W_m = \left[\varepsilon_m^{\text{Level}}, \varepsilon_m^{\text{Slope}},\ vix_m,\ gdp_m,\ cpi_m,\ urate_m,\ ffr_m,\ 10yrate_m\right]',$$

where vix_m is the VIX ($100 \times \log$), gdp_m is the monthly GDP measure from Macroeconomic Advisors ($100 \times \log$), cpi_m is the CPI ($100 \times \log$), $urate_m$ is the unemployment rate, ffr_m is the Federal Funds rate, and $10yrate_m$ is the 10-year Treasury rate.

The choice of the control variables is mostly standard. Since the Federal Funds rate is at the Zero Lower Bound for most of the sample period, I include both the Federal Funds rate and the 10-year Treasury rate to parsimoniously capture changes in the entire yield curve (Eberly, Stock, and Wright, 2019). I include 12 lags of each variable as is commonly done at monthly frequency. Following (Ramey, 2016), I also include lags of the shock series themselves to make sure that serial correlation of the shock series is not driving any of the results. The sample period runs from 2009m1 to 2020m1.

Figure 5 shows the impulse responses to a one standard deviation shock of $\varepsilon^{\text{Level}}$. Overall, the impulse responses are quite "jumpy" due to the local projection technique and the small sample. The sample size is also the reason why I only estimate the responses up to a horizon of 18 months. Despite that, there are multiple important points to make here. First, the VIX shows the expected response as it increases on impact. Second, there is a contraction in real activity after a couple of months, as real GDP falls and the unemployment rate rises. Third, CPI falls and hence the shock looks like a negative demand shock. Lastly, the shock does not look like a typical monetary policy shock emphasized in the literature. The Federal Funds rate does not respond, and the 10-year Treasury rate decreases likely due to the drop in the CPI. This is a reassuring result confirming that my identification purges out interest rate traditional monetary policy shocks.

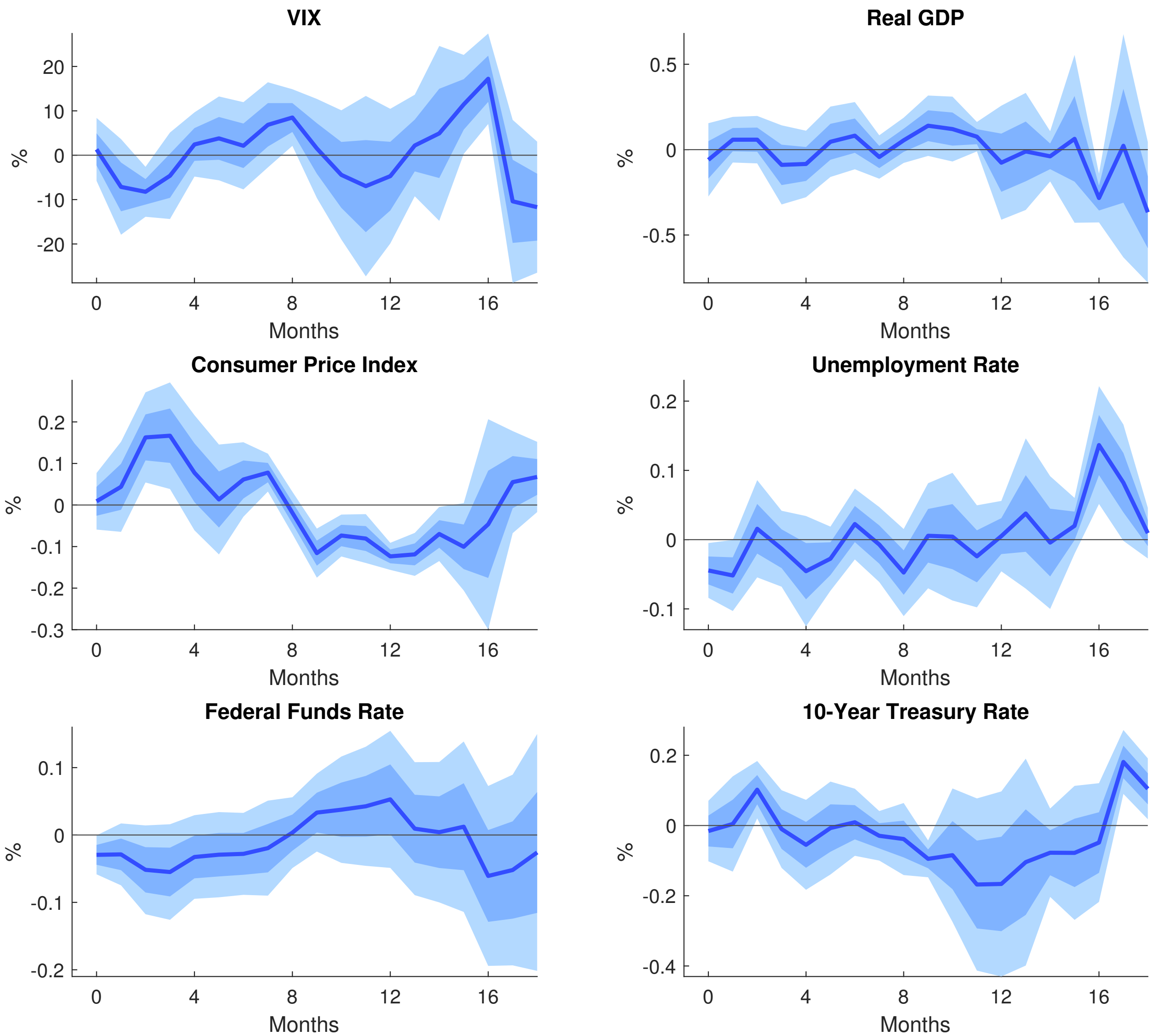
Figure 5: Impulse Responses to the VX Level Shock



Notes: This figure shows the impulse responses estimated from the local projection specification (2) to a one standard deviation shock of $\varepsilon_m^{\text{Level}}$. The dark and light blue bands display the 68% and 95% confidence bands, respectively. Newey-West standard errors are employed.

Figure 6 shows the impulse responses to a one standard deviation shock of $\varepsilon^{\text{Slope}}$. The VIX slightly falls in the first months with a subsequent rise. Real activity, i.e. real GDP and the unemployment rate, is mostly unaffected over the first months, and shows signs of a contraction after a year. The CPI is going up, and down. Overall, the results are harder to interpret than for the $\varepsilon^{\text{Level}}$ shock. This could be due to the fact that the shock $\varepsilon^{\text{Slope}}$ increases parts of the VIX term structure, and decreases other parts.

Figure 6: Impulse Responses to the VX Slope Shock



Notes: This figure shows the impulse responses estimated from the local projection specification (2) to a one standard deviation shock of $\varepsilon_m^{\text{Slope}}$. The dark and light blue bands display the 68% and 95% confidence bands, respectively. Newey-West standard errors are employed.

5 Conclusion

In this paper, I construct new shock measures of monetary policy by employing high-frequency data on VIX futures. The constructed shocks are orthogonal to traditional measures of monetary policy shocks. Studying their effect on macroeconomic variables, I find evidence of a transmission to real economic activity through the effect on the VIX. Overall, my results emphasize the information content of monetary policy beyond their impact on the yield curve.

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