Trading Volume and Monetary Policy Surprises

Jonas Camargos Jensen

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Abstract

High-frequency identification of the causal effects of monetary policy relies on measuring monetary policy surprises–changes in interest rate futures prices in narrow windows around FOMC announcements capturing unexpected shifts in market-based interest rate expectations. Constructing these surprises entails two key heuristic choices: the event window and the set of interest rate futures contracts. This paper introduces the Volume-Based Monetary Policy Surprise (VBS), which uses abnormal trading volume to let the market endogenously determine the relevant event windows, set of futures contracts and their loadings in the resulting surprise measure for each announcement. The announcement-specific event windows flexibly capture when prices continue adjusting beyond conventional 30-minute windows and when relevant information is released during press conferences. The announcement-specific loadings naturally shift toward longer-dated contracts when the Federal Reserve relies on forward guidance about future policy. The VBS doubles the estimated impact of monetary policy on Treasury yields and equity markets and has a sizable impact on macroeconomic aggregates.

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Frankfurt School of Finance & Management Email: j.jensen@fs.de

1 Introduction

Identifying causal effects of monetary policy is fundamental to understanding how central banks influence financial markets and the economy. In recent years, a widely adopted methodological approach employs surprises derived from high-frequency asset price movements in tight windows, typically 30 minutes, around Federal Open Market Committee (FOMC) announcements. These surprises function as plausibly exogenous instruments, capturing unanticipated policy changes orthogonal to contemporaneous economic conditions. As monetary policy communication has evolved beyond simple federal funds rate announcements, empirical measures of monetary policy surprises have incorporated both information about the federal funds target rate (Kuttner, 2001) and the expected path of interest rates (Gürkaynak et al., 2005) into a single surprise measure (Nakamura and Steinsson, 2018).

Two critical questions underlie the high-frequency-approach to measuring monetary policy surprises. First, how long do markets take to process the information contained in FOMC announcements? Existing measures employ fixed window lengths, with 30-minute intervals representing the standard (Gürkaynak et al., 2005). Shorter windows increase the precision of the surprise by minimizing contamination from other macroeconomic news, but risk truncating the market's full adjustment to the new information. Second, which interest rate futures contracts contain the most policy-relevant information, and how does this composition change as the FOMC's communication evolves? Conventional measures extract factors from a set of interest rate securities with fixed loadings over the entire sample period but commonly restrict the maturity spectrum to contracts maturing within 12 months. While longer-maturity contracts can capture longer-dated forward guidance, they historically exhibited relatively low liquidity.

This paper introduces the Volume-based Monetary Policy Surprise (VBS) which lets the market endogenously determine the relevant announcement-specific event windows, set of interest rate futures contracts, and their loadings. I leverage the fact that for the Eurodollar futures market, which is commonly used to measure the path of interest rate expectations, not only price data but also trading volume is available at a high frequency. Trading volume reveals market participants' incentives to trade on new information when information is dispersed (He and Wang, 1995; Vives, 1995; Banerjee and Kremer, 2010). For each FOMC announcement, I establish a baseline of normal expected volume that would prevail in its absence. The announcement-specific window length extends until realized trading volume returns to this baseline and each contract's loading in the VBS equals its share of total volume over the event window. The VBS thus is the volume-weighted average price change in the Eurodollar futures market which naturally shifts to the segment of the term structure where market attention is focused.

My main empirical finding is that monetary policy has substantially larger effects on financial markets than conventional measures suggest. For Treasury securities, a contractionary Volume-based Monetary Policy Surprise generates responses in nominal yields roughly twice as large, with particularly pronounced effects on real yields across the entire maturity spectrum. For equity markets, the estimated impact is also twice as large and the VBS explains five times more variation in daily stock returns around FOMC announcements. These differences have grown over time: prior to 2004, the VBS and conventional measures largely coincide, but they diverge substantially in the modern era of press conferences, detailed forward guidance and electronic markets enabling extended post-announcement trading.

These findings extend to the estimated effects of monetary policy on the economy. Using the VBS as an instrument in vector autoregressions and local projections generates large negative CPI responses to contractionary shocks, addressing a well-documented puzzle in the literature on high-frequency identification of insignificant inflation responses (Gertler and Karadi, 2015; Ramey, 2016). The results are driven by the part of the VBS measuring expectations about the path of interest rates, which displays economically intuitive responses of macroeconomic aggregates without the puzzling patterns observed with conventional path measures. These results are complementary to recent work showing that controlling for the Fed's information set (Miranda-Agrippino and Ricco, 2021) or economic news (Bauer and Swanson, 2022) can increase the estimated real effects of monetary policy shocks identified through high-frequency surprises. Adjusting for these predictors, the relative performance of the VBS remains unchanged, consistently generating even larger and more precisely estimated real effects.

Three features of the VBS methodology explain these results. First, announcement-specific windows allow for extended processing of complex FOMC statements, capturing price adjustments that continue well beyond 30 minutes. Second, the windows endogenously incorporate press conferences when volume remains elevated during the chair's public remarks. Third, announcement-specific loadings capture shifts in market attention toward medium-dated forward guidance, particularly following the publication of FOMC members' policy rate projections ("dot plots"), as trading volume migrates to longer-maturity contracts. In summary, allowing markets to reveal when and where they are surprised substantially improves the measurement of monetary policy surprises and enhances our understanding of the monetary transmission mechanism.

The paper proceeds in three parts. In the first part, I document three novel facts about price discovery in Eurodollar futures markets. First, volume and volatility remain abnormally elevated with both staying significantly above normal levels for up to 90 minutes, contrasting sharply with the current-month federal funds futures (Kuttner, 2001), where market reactions occur within the conventional 30-minute windows. Second, Eurodollar futures exhibit gradual price adjustment, requiring on average 45 minutes to reach their new level following announcements without press conferences. Third, the Eurodollar futures volume moves substantially towards contracts with interest rate expectations of up to three years around FOMC announcements.

The second part develops the VBS methodology. For each FOMC announcement, I establish baseline expected volume from the prior 21 trading days, defining the window as the period when realized volume exceeds this baseline. Contract loadings equal their share of total volume over the event window, naturally weighting where market attention is focused. The resulting windows exhibit substantial variation over time: averaging 41 minutes during pit trading (1988-2003) and extending to 60 minutes for regular announcements and 100 minutes for press conferences in the electronic era (2004 onwards). Contract loadings shift even more dramatically—during the zero lower bound, contracts maturing beyond two years capture over 40% of volume while near-term contracts fall below 20%, reflecting the Fed's increasing reliance on forward guidance. This generates a sharp divergence between measures: pre-2004, the conventional measure explains 85% of the VBS; post-2004, this falls to 0.52 as conventional measures miss both the extended processing time and the shift toward longer maturities.

This unexplained variation can be separated into two components that determine the contribution of the announcement-specific window lengths and the volume-weighted loadings respectively. There are two key drivers of the extended window lengths. First, window lengths correlate strongly with statement dissimilarity-approximating the new information within the FOMC press release-on days without a press conference. Second, press conferences themselves become important during the tightening cycle in 2021 leading to substantial differences between 30-minute surprises and the VBS. The volume-weighting matters particularly between 2011 to 2015 when the Fed relied heavily on forward guidance and the dot-plot was introduced. There is a strong correlation between the volume-weighting component and the difference in median forecasts from the Primary Dealer Survey, which surveys market participants prior to the FOMC meeting, and the FOMC members' median dot-plot forecast at the same horizon. Therefore, the volume-weighting component captures the market's shift toward longer-dated contracts when figuring out the lift-off from the zero lower bound and the subsequent path of interest rates.

The third part establishes the economic significance of these changes, focusing on the period since 2004 when windows become longer and forward guidance more important. For Treasury markets, a one-standard-deviation contractionary VBS shock generates peak effects around 5 basis points on nominal yields—roughly twice the response captured by conventional measures—with statistically significant effects extending out to 14-year maturities compared to only 6 years for conventional measures. The decomposition into real yields and breakeven inflation reveals that monetary policy affects both components: real yields show particularly persistent effects across the entire maturity spectrum, while breakeven inflation displays a significant negative level shift of around 2 basis points. For equity markets, the differences are even more pronounced. A one-standard-deviation contractionary shock reduces daily stock prices by 0.43 percent, while conventional measures suggest only a 0.22 percent decline that is no longer statistically significant. Moreover, the VBS explains 15 percent of daily stock return variation around announcements compared to just 3 percent for conventional measures.

These large differences between the VBS and conventional measures have grown over time. Prior to 2004, when Eurodollar futures traded primarily in the pit and trading volume concentrated in the first four quarterly Eurodollar contracts, the VBS and conventional measures perform similarly, generating comparable coefficient estimates and explanatory power for both Treasury yields and equity returns. However, the measures diverge substantially beginning in 2004. Conventional measures suggest a drastic weakening of monetary policy's influence: estimated impacts on Treasury yields decline markedly and equity market effects become statistically insignificant. In contrast, the VBS shows that monetary policy's influence has remained strong throughout.

The VBS also has substantial effects on macroeconomic outcomes. Using the VBS as an internal instrument in a structural VAR spanning 1988/11-2020/02, a one-standard-deviation contractionary shock reduces CPI by 0.1 percentage points at peak impact—a statistically significant and economically meaningful response. The identical specification using conventional measures yields negligible and insignificant inflation responses. The baseline results are established using the internal instrument approach (Plagborg-Møller and Wolf, 2021) and a VAR that is estimated with a flat prior but the results are robust to different estimation methods, including local projections (Jordà, 2005) and shrinkage priors (Litterman, 1986) as well as identification through the external instrument approach (Mertens and Ravn, 2013). In addition, adjustments for predictability from financial conditions (Bauer and Swanson, 2022) and the Fed's information set

(Miranda-Agrippino and Ricco, 2021) do not affect these results, with the VBS consistently generating larger and more precisely estimated real effects.

These differences are entirely driven by the path component: conventional path measures often generate price puzzles and positive inflation responses suggesting confounding information effects (Lakdawala, 2019; Swanson, 2023), while the VBS path component produces theoretically consistent negative inflation responses. In particular, the sustained negative inflation response is due to the volume-weighting component, capturing the explicit rate path communicated in the dot-plot. Therefore, these findings shed a new light on the importance of forward guidance for monetary transmission.

Related Literature and Contribution

This paper contributes to the literature on the measurement of monetary policy surprises. The foundational paper is Kuttner (2001), who proposes isolating the level ("Target") change in the federal funds rate from daily changes in federal funds futures around FOMC announcements. Building on this work, Gürkaynak et al. (2005) include Eurodollar futures that mature within 12 months to capture effects on the path ("Path") of interest rates and, importantly, propose the use of intraday data and the 30-minute window. The shift to a 30-minute window addresses the issue of some early 1990s FOMC actions occurring immediately after employment reports and has since been widely adopted in the literature. While Gürkaynak et al. (2005) separate the effects by estimating two factors, the literature subsequently often summarizes the effects into a single surprise measure capturing the total monetary policy surprise (Nakamura and Steinsson, 2018; Acosta et al., 2024; Bauer and Swanson, 2023). This single surprise measure estimates the first principal component over 30-minute changes in a combination of federal funds futures (Kuttner, 2001) and Eurodollar futures that expire within 12 months and is the benchmark surprise to which I compare the Volume-based Monetary Policy Surprise measure. Several surprise measures incorporate other dimensions of monetary policy (Kaminska et al., 2021; Swanson, 2021; Kroencke et al., 2021; Acosta et al., 2025) but importantly keep the assumptions of fixed window lengths and fixed loadings, varying only the set of asset prices included in the surprise construction. The notable exception is Lewis (2023), who uses an identification-by-heteroskedasticity approach to identify announcement-specific loadings. This paper's contribution is to measure announcement-specific window lengths and loadings that are determined by observable market behavior—trading volume—and can be motivated from economic theory.

Second, this paper contributes to the literature on the effects of monetary policy on financial markets. The literature documents that conventional monetary policy has a sizable impact on interest rates, particularly long-term interest rates (Gürkaynak et al., 2005). It has been proposed that this impact is driven by bond risk premia (Hanson and Stein, 2015; Kekre et al., 2022) or trend inflation (Gürkaynak et al., 2005). My results show that monetary policy has a sizable impact on both, long-term real rates and inflation expectations. The link between monetary policy and equity markets has also been extensively studied, with Knox and Vissing-Jorgensen (2025) providing a recent survey. Closest to this paper are Bernanke and Kuttner (2005), who investigate the response of daily stock prices to the target surprise, and Gürkaynak et al. (2005), who conduct a high-frequency event study of equity returns on target and path. I show that up until 2004, which closely aligns with the samples in both studies, both the conventional 30-minute principal component surprise and the VBS lead to a large and negative impact of monetary policy on equity prices. However, since 2004, only the VBS leads to a large and significant decline in equity prices, which is consistent with evidence of how markets behave around press conferences (Gómez-Cram and Grotteria, 2022; Acosta et al., 2025). These results have implications for stock return decompositions into discount rate and cash flow effects (Knox and Vissing-Jørgensen, 2022; Nagel and Xu, 2024; Golez and Matthies, 2025) which rely on dividend strip and futures data that is only reliably available since the early 2000s.

I also contribute to the literature studying the impact of monetary policy on macroeconomic aggregates. One finding in this literature is a relatively weak inflation response (Gertler and Karadi, 2015; Ramey, 2016), and much focus has been dedicated to how to adjust monetary policy surprises to incorporate the learning problem the market faces when deciphering FOMC communication. There is an ongoing discussion about whether market participants learn about shifts in the way the FOMC will react to news and fundamentals (Bauer and Swanson, 2022, 2023) or whether the FOMC has different information about those fundamentals (Jarociński and Karadi, 2020; Miranda-Agrippino and Ricco, 2021; Ricco and Savini, 2025; Jarociński and Karadi, 2025). Importantly, these papers focus on the role of imperfect information between markets and the central bank but take the measurement of the high-frequency monetary policy surprise with its fixed window length and loadings as given. This paper shows that adjusting these assumptions by using observed volume—a measure that is inherently driven by heterogeneity among market participants—matters substantially for the estimated effects of monetary policy on the economy and asset prices.

Third, this paper contributes to the literature on trading around public announcements. Abnormal volume around public announcements has been documented in Beaver (1968); Fleming and Remolona (1999); Green (2004). This has led to several theoretical investigations discussing when and how volume can arise in financial markets and examining departures from the No-Trade Theorem (Milgrom and Stokey, 1982). Using volume to identify window lengths and loadings can be motivated by dynamic noisy rational expectations models (He and Wang, 1995; Vives, 1995) and dynamic differences-of-opinion models (Banerjee and Kremer, 2010) that model how dispersed information gets incorporated over time and can generate realistic patterns of volume and volatility. Variants of these models (Allen et al., 2006; Cespa and Vives, 2012, 2015) can generate the slow predictable pattern in prices that this paper documents. The contribution of this paper is applying these insights to the measurement of monetary policy surprises and providing empirical evidence on the behavior of the Eurodollar market on FOMC announcement days.

Lastly, this paper is connected to the literature on central bank communication with financial market participants and the public, which is surveyed by Blinder et al. (2024). Similar measures of statement dissimilarity have been developed in Ehrmann and Talmi (2020) and Handlan (2022). This paper contributes establishes the link between the information conveyed by the central bank and the duration it takes markets to process that information. The window lengths identified in this paper provide a natural measure to evaluate the effectiveness of complex central bank communication on financial markets.

2 Monetary Policy Surprises

This section discusses the typical construction of monetary policy surprises around FOMC announcements, the relevant FOMC announcement timestamps, and the high-frequency data used to construct the Volume-based Monetary Policy Surprise (VBS) and the benchmark 30-minute surprise by principal components

(30M-PC) as in Nakamura and Steinsson (2018).

Monetary policy surprises are commonly extracted from high-frequency changes in interest rate futures around FOMC announcements

$$s_{m,x=\overline{x}+\underline{x}} = \Lambda(f_{m,t+\overline{x}} - f_{m,t-\underline{x}})$$

where s_m represents the surprise around meeting m, $f_{t+\overline{x}}$ and $f_{t-\underline{x}}$ denote implied interest rates at the upper and lower window bounds, and Λ maps multi-dimensional implied interest rate changes to the surprise measure.

The implied interest rate is derived from short-term interest rate futures prices. A short-term interest rate future with price $P_{t,h}$ and maturity h at time t will settle at $100 - r_{t+h}$, where r_{t+h} is the underlying reference rate at time t+h. Under risk-neutrality, the implied interest rate today $f_{t,h} = 100 - P_{t,h}$ measures the time t expectation of the underlying reference rate at maturity $t + h$

$$f_{t,h} = E_t(r_{t+h}).$$

Therefore, under the assumption of constant risk premia, the changes in implied interest rates capture changes in market expectations of future interest rates. (Piazzesi and Swanson, 2008) show that while these contracts have risk premia, these matter less in short-windows around FOMC announcements.

The benchmark I use throughout this paper is the 30-minute Policy News Surprise (30M-PC) developed by Nakamura and Steinsson (2018). It combines the target and path surprise into a single measure to summarize the overall monetary policy surprise over a long sample period, motivated by the fact that target level changes capture only a small fraction of monetary policy news on the FOMC announcement day.

It implements the following choices for the window length $x = \overline{x} + \underline{x}$ and the loading matrix Λ and the set of prices included. The window length is set to 30 minutes, with the lower bound being 10 minutes and the upper bound being 20 minutes. This is an assumption commonly used in the literature dating back to Gürkaynak et al. (2005) who find that 30-minute and 60-minute windows produce relatively similar results in high-frequency event studies for the target surprise, albeit they find some differences in the estimated effects to the path surprise. By construction, this window only focuses on the press release statement and later in the sample the survey of economic projections when released jointly.

The loading matrix Λ is estimated using Principal Component Analysis (PCA) on these 30-minute price changes, summarizing the common movements across the term structure of interest rate futures. The prices included cover the current-month federal funds futures and Eurodollar futures contracts with maturities up to 12 months. I calculate the 30M-PC for the set of FOMC announcement specified above using the high-frequency data described described below. I include the current-month Federal Funds futures and the first four quarterly Eurodollar futures. Historical front-month federal funds futures changes up to 1988 are taken from Gürkaynak et al. (2005). The only change to the specification in Nakamura and Steinsson (2018) is that I use the first quarterly Eurodollar future to capture interest rate expectations between 1-3 months instead of the next-meeting federal funds future. This change does not matter empirically - the resulting 30M-PC has a correlation of 0.99 with other versions 30M-PC calculated in Bauer and Swanson (2023) and Acosta et al. (2024) over the matching sample.

Federal Open Market Committee Announcement Timestamps

The Federal Open Market Committee (FOMC) meets eight times a year to decide on the monetary policy stance of the Federal Reserve. The FOMC announces its decision on the federal funds target rate, which is the interest rate at which banks lend reserves to each other overnight. The announcement is typically made at 2:00 PM Eastern Time, and it is widely anticipated by market participants.

The FOMC announcement timestamps are taken from (Bauer and Swanson, 2023) [1]. During the sample period of November 1988 to December 2022, there were 304 FOMC rate decisions of which 274 are scheduled and 32 unscheduled. I consider all events that are contained in both (Gürkaynak et al., 2005) and (Bauer and Swanson, 2022) as the Gürkaynak et al. (2005) dataset contains front-month federal funds futures changes up to 1988 which are only available from the CME from 1995 onwards. This empirical measure is required to construct the benchmark surprise measure over the full sample (Nakamura and Steinsson, 2018).

The FOMC's communication strategy has evolved substantially over the sample period. Between 1988-1993, the FOMC released no information to the public; instead, actions have to inferred from trading desk operations (Cook and Hahn, 1989), with most actions occurring at 11:30am. This changed in February 1994 when the Federal Reserve sent out a press detailing its reasoning for a rate change at 11:05 am for the first time. The Fed continued to release a statement accompanying all meetings where policy rates were changed, but moved it to 2:15 pm in the afternoon. Since May 1999, a statement has been released at every meeting, even when no policy changes are made.

Since April 2011, the Fed has held press conferences four times per year, expanding to every meeting since 2019. When press conferences occured on a quarterly schedule, they are accompanied by a table summarizing the the Summary of Economic Projections, forecasts of individual FOMC meeting participants. This statement is complemented by the Federal Reserve's Dot Plot, which shows the Individual FOMC members' projections for the federal funds rate at the end of the current year, the next two years, and the longer run since January 2012. In contrast, to the potentially more implicit information about the path of interest rates in the press release, the Dot Plot provides explicit information about the FOMC's expectations for the federal funds rate at different horizons.

During April 2011 through the end of 2012, when a press conference was scheduled the press release was moved to 12:30 pm, the Summary of Economic Projections was released at 2:00 PM ET and the press conference occured at 2:15 PM ET. Since 2013, the press release is scheduled at 2:00 PM Eastern Time and with the summary of economic projections released jointly when prepared, and press conferences held at 2:30 PM ET. In total, 65 of the scheduled FOMC statements in my sample are accompanied by a press conference, while there are 44 FOMC statements with a Dot Plot.

In summary, there are substantial changes in the FOMC's communication strategy over the sample period with more information being released to the public in close vicinity to the FOMC press release.

High-Frequency Data

The primary dataset for the analysis is the Time and Sales dataset provided by the Chicago Mercantile

[1] An updated version of the dataset is provided by the San Francisco Fed under the following link https://www.frbsf.org/research-and-insights/data-and-indicators/monetary-policy-surprises/

Exchange. This dataset comes in two files for each trading day. The first covers the Trading Pit ("Restricted Trading Hours"/RTH) while the second file covers electronic trading on the CME's Globex platform ("Extended Trading Hours"/ETH). In the discussion below, I focus particularly on Eurodollar futures contracts, which are the most liquid short-term interest rate futures contracts and the primary instrument used to measure the path of interest rates in the literature on monetary policy surprises (Gürkaynak et al., 2005; Nakamura and Steinsson, 2018; Swanson, 2021) but the structure is similar for other contracts such as federal funds futures and (E-mini) S&P 500 futures.

The Eurodollar Futures Trading Pit was historically open from 8:20 AM to 3:00 PM Eastern Time (ET) on all business days. For all FOMC announcements which were scheduled at 14:15 pm post-announcement trading was limited to a maximum of 45 minutes. Electronic trading becomes the dominant mode for Eurodollar futures in the Times and Sales Dataset in December 2003, when the number of transactions in the electronic market exceeds the number of transactions in the pit which also matches anecdotal evidence from the CME (Melamed, 2009). Eurodollar futures contracts are traded continuously throughout the week, apart from a 1-hour daily maintenance period at 16:00/17:00 (CT/ET). I focus on the subset between 05:00/06:00 until 16:00/17:00 (CT/ET), the start of the maintenance period. This is sufficient to capture all relevant trading activity around scheduled and unscheduled FOMC announcements. Therefore, I use the Trading Pit data with its regular trading hours until November 2003 and the electronic trading data until December 2022 when most of the market volume moved to SOFR futures (Acosta et al., 2024).

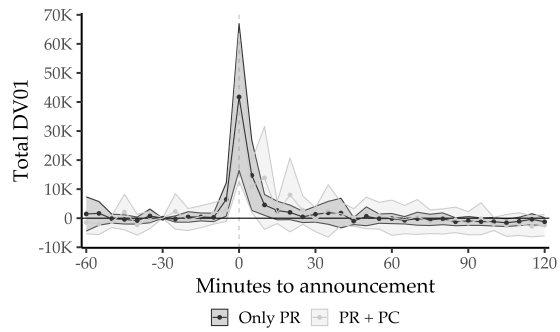
From both files I obtain transaction timestamps, prices, and, for electronic trading, transaction volumes expressed in the number of contracts. Trading volume in the Trading Pit can be approximated by the number of trades as the number of contracts traded is not available. I create a minute-by-minute dataset of prices and trading volume for the two monthly serials and first twelve quarterly Eurodollar futures contracts, the front-month federal funds futures contract and the currently actively traded E-mini S&P 500 futures contract. E-mini S&P 500 futures are only traded electronically and for fed funds futures the switch to electronic trading occurs roughly at the same time as for Eurodollar futures. For the front-month federal funds futures contract, I use the current-month contract up until the last seven days before the contract expires when I switch to the second-month contract. In cases where no trading occurs in a given minute, I fill the dataset backwards with the last available price and set the trading volume to zero.

I keep for each FOMC announcement timestamp at most the past 21 trading days and the FOMC announcement day itself. The pre-announcement part can contain less than 21 trading days as for some days there are files missing in the Time and Sales dataset. One particular unfortunate example is the FOMC announcement day 2014-01-29, where the Time and Sales dataset is missing the entire day. Therefore, I exclude this announcement from all analysis in this paper. This should not affect the results as the 30-minute changes in the first four Eurodollar contracts are below 0.0025 bp in the Bauer and Swanson (2022) dataset.

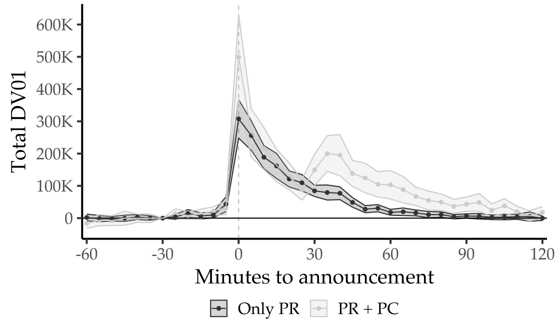
Short-Term Interest Rate Futures Market Around FOMC Statement Releases

Fleming and Remolona (1999) show that government bond markets display substantial abnormal volume and volatility after macroeconomic news releases and argue that this is due to dealers resolving their private interpretations until the market converges. Appendix A details how the FOMC announcement day can be viewed through the lens of the literature of asset pricing under asymmetric information that can rationalize these patterns. Therefore, I verify if the same empirical patterns hold in short-term interest rate futures market around FOMC statement releases. I document three key facts about the behavior of short-term interest rate futures markets around FOMC announcements since December 2003 when trading occurs electronically which allows for extended post-announcement trading.

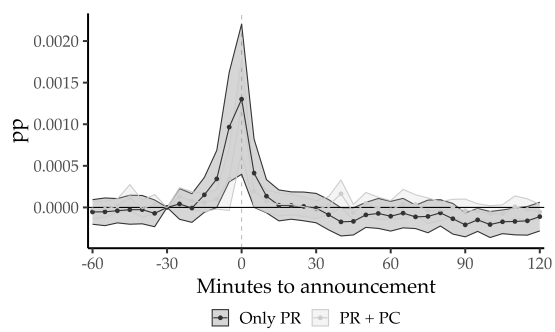
Figure 1: Trading Volume and Absolute Price Changes Around FOMC Announcements



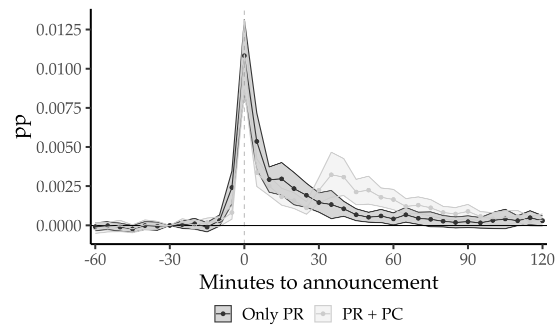
(a) Front-Month FFR Future Volume



(b) Eurodollar Futures Volume



(c) Front-Month FFR Future Volatility



(d) Q1-Q12 Eurodollar Futures Volatility

Panels (a) and (b) show the estimated $\hat{\beta}_k$ and their 99% confidence intervals from

$$Volume_{m,d,\tau} = \alpha_{m,\tau} + \alpha_d + \sum_{\substack{k=-60 \\ k\neq -30}}^{120} \beta_k \cdot \mathbb{1}\{\tau = k\} \cdot FOMC_d + \epsilon_{m,d,\tau}$$

where m indexes FOMC meetings, d denotes the calendar day, τ denotes event time in minutes relative to the FOMC announcement (in 5-minute intervals), and $FOMC_d$ is an indicator equal to one on FOMC announcement days. Panels (c) and (d) show the estimated $\hat{\beta}_k$ and their 99% confidence intervals from

$$|\Delta P_{c,m,d,\tau}| = \alpha_{c,m,\tau} + \alpha_{c,d} + \sum_{\substack{k=-60 \\ k\neq -30}}^{120} \beta_k \cdot \mathbb{1}\{\tau = k\} \cdot FOMC_d + \epsilon_{c,m,d,\tau}$$

where c denotes the contract and other subscripts are as defined above. In both panels, the baseline period is $\tau = -30$ and the sum is over 5-minute intervals: $k \in \{-60, -55, -50, \ldots, 115, 120\}$. The coefficients are estimated by OLS. The sample runs from 2003-12-01 to 2022-12-31 and contains all scheduled FOMC announcements and the 21 prior trading days. The vertical line indicates the FOMC announcement at $\tau = 0$. Standard errors are clustered at the day level.

First, volume and volatility patterns are abnormally high and stay elevated in the Eurodollar market. Figure 1 illustrates the dynamics of trading volume and absolute price changes around FOMC announcements for the front-month federal funds futures and the first twelve Eurodollar futures. It rescales volume to DV01 which allows a size comparison between the volume response in the federal fund futures contracts and the

Eurodollar market. In both markets, the DV01 denotes the dollar value change to a 1 basis point change in the underlying interest rate, which are 41.67$ for federal funds futures and 25$ while for Eurodollar futures.

Since the FOMC announces the new level federal funds target rate, the front-month federal funds futures contract adjusts immediately to the new information. There is a short-lived spike in trading volume that lasts for about 10-15 minutes, after which trading volume returns to normal levels.

In contrast, trading volume in Eurodollar futures contracts spikes significantly around the FOMC announcement, with the initial spike representing an increase in contracts worth 300-500 thousands. This is substantially larger than the initial spike in the front-month federal funds futures contract, which is around 40K DV01. This comparison might seem unfair at first sight as compares 12 Eurodollar futures to one federal funds future, but in the federal funds futures market volume is heavily concentrated in the front-month contract. Importantly, this elevated volume persists well beyond conventional measurement windows, remaining significantly above normal levels for 75 to 100 minutes, depending on whether a press conference is held. The press conference can contain another noisy public signal about the policy indicator i_m. During press conferences, the volume picks up again, indicating that market participants are actively processing the additional information provided during the press conference.

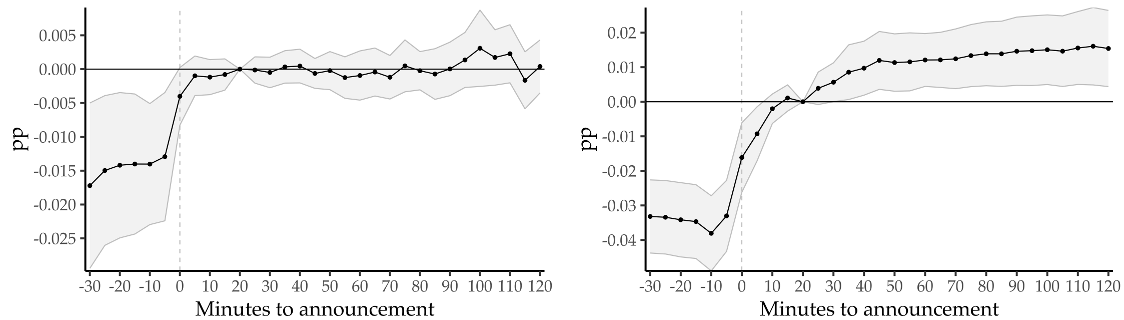
The results for volatility mirror those for trading volume. The front-month federal funds futures contract experiences a sharp increase in price volatility immediately after the FOMC announcement, which quickly subsides within the first 10 minutes. In contrast, Eurodollar futures contracts exhibit a significant spike in price volatility that persists for an extended period, remaining elevated for 75-90 minutes after the announcement.

As in Fleming and Remolona (1999), these volume and volatility suggest substantial information processing within the Eurodollar futures market. Appendix B.3 shows that similar patterns emerge when using a Poisson regression to model the percentage change in volume. Importantly, volume is still 500% higher 20 minutes after the announcement compared to 30 minutes before the announcement, indicating that the market is still actively processing information well beyond the conventional 30-minute window. Similar patterns also emerge for other asset classes, such as E-mini S&P 500 futures, as shown in Appendix B.5.

Secondly, prices take on average 45 minutes after the announcement to reach their new level. Figure 2 shows the cumulative absolute price changes in the front-month federal funds futures and the first twelve Eurodollar futures around FOMC announcements without a press conference. The results reveal a striking difference between the two markets. For the front-month Fed Funds Future, there is a 1.5 basis point price change over the conventional 30-minute window, but this change is virtually indistinguishable from the immediate price movement after the press release (1 basis points on average). The federal funds futures market appears to process information almost instantaneously.

In contrast, Eurodollar futures exhibit gradual price discovery. Prices gradually adjust to FOMC information and reach their new level slowly. The average cumulative absolute price change reaches 4 basis points over the first 30 minutes but crucially continues increasing by another basis point until stabilizing at 5 basis points after 45 minutes. Therefore, a 30-minute window captures on average only 80% of the total price

Figure 2: Cumulative Absolute Price Changes



(a) Front-Month FFR Future **(b)** Q1-Q12 Eurodollar Futures

Figure shows $\hat{\beta}_k$ and their 99% confidence intervals from

$$|P_{c,m,\tau} - P_{c,m,-10}| = \alpha_{c,m} + \sum_{\substack{k=-30 \\ k\neq 20}}^{120} \beta_k \cdot \mathbb{1}\{\tau = k\} + \epsilon_{c,m,\tau}$$

where c denotes the contract, m indexes FOMC meetings, and τ denotes event time in minutes relative to the FOMC announcement. The baseline period is $\tau = 20$. The regression is estimated using only FOMC announcement days. The sample runs from 2003-12-01 to 2018-11-08 and contains all scheduled FOMC announcements where no press conference was held. Event time runs from $\tau = -10$ to $\tau = 120$, where $\tau = 0$ indicates the FOMC statement press release. Prices are sampled at the 5-minute frequency. The coefficients are estimated by OLS and standard errors are clustered at the meeting level. The baseline period $\tau = 20$ represents the cumulative absolute price change in the 30-minute window of Gürkaynak et al. (2005).

adjustment in Eurodollar futures, missing significant information content that continues to be incorporated over longer horizons. In appendix B.2, I document that this reprents an inefficiency which could have been exploited with a simple short-run momentum strategy up until the introduction of press conferences in March 2011. This strategy delivers a Sharpe ratio of 1.03 over 146 FOMC announcements without a press conference between February 1994 and March 2011. In addition, the strength of the initial jump and the speed of adjustment varies substantially across announcements. In appendix B.3, I show substantial variation in the price responses which vary with empirical proxies for amount of new information, signal precision and residual uncertainty.

Third, trading volume in Eurodollar futures increases substantially after the introduction of electronic trading, with activity shifting toward longer-dated contracts. Figure 3 illustrates this evolution by showing trading volume across contract maturities on FOMC announcement days.

When Eurodollar futures were primarily traded in the Pit (before December 2003), trading volume was heavily concentrated at the front of the curve, with the first four quarterly contracts accounting for the majority of activity. This concentration motivated the literature's focus on these contracts (Gürkaynak et al., 2005) to capture the path of interest rates.

The transition to electronic trading in December 2003 brought two key changes. First, overall trading volume increased significantly as electronic platforms enabled broader market participation and extended trading hours. Second, volume became more evenly distributed across the term structure, with substantial activity shifting to longer-dated contracts. This redistribution is particularly pronounced during the zero lower bound period, when the first four quarterly contracts account for only a small fraction of total FOMC-day trading volume.

Figure 3: Eurodollar Futures Volume on FOMC Announcement Days

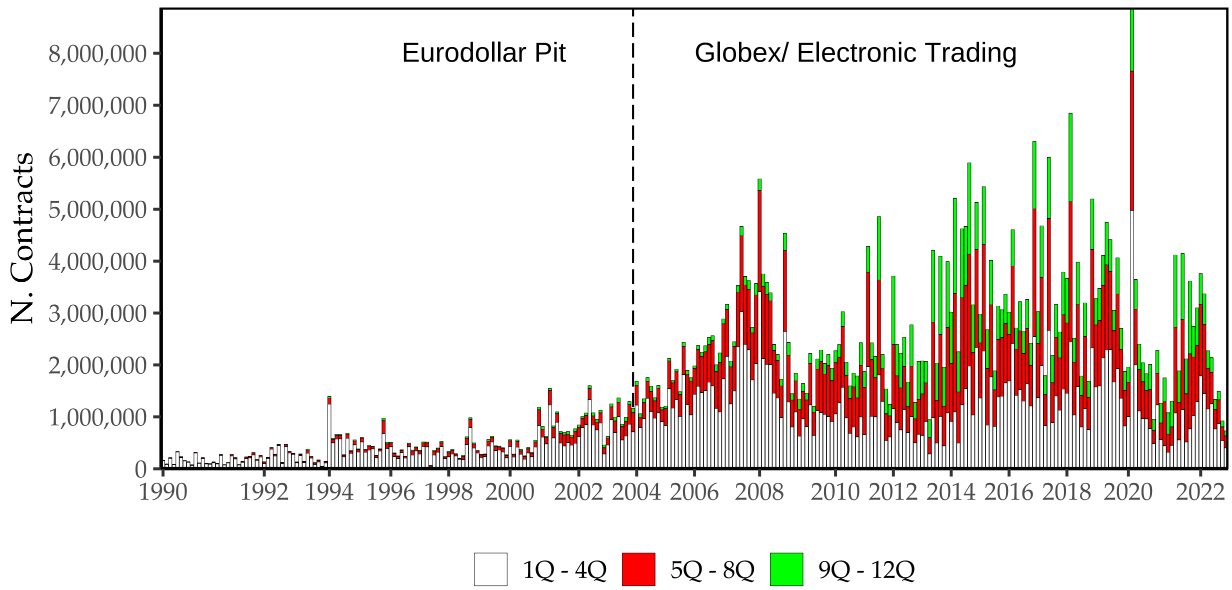


Figure shows the trading volume (contracts) in the first 12 quarterly Eurodollar futures, aggregated by contract maturity, on the FOMC announcement day. The data is from Bloomberg as the Time and Sales dataset does not contain volume for trades in the Eurodollar Pit. The dashed vertical line indicates the meeting in December 2003, when the number of transactions in electronic trading overtakes Pit trading in the Time and Sales dataset.

Given the evidence of dispersed information across market participants—as reflected by elevated trading volume—a natural question emerges: in which contracts is this information concentrated? In term structure models with imperfect information, demand and volume concentrate in assets with the most dispersed information (Barillas and Nimark, 2017). Therefore, the large spikes between 2010 to 2022 point to important informational events that move volume in short-term interest rate futures markets to contracts with interest rate expectations beyond twelve months.

3 Volume-Based Monetary Policy Surprise

The empirical findings from Section 3 revealed three key facts about the Eurodollar market around FOMC announcements. First, there is a significant spike in trading volume and price volatility that persists for an extended period, indicating gradual price discovery. Second, prices gradually adjust up to their new 45 minutes after the announcement, but these price trajectories vary based on empirical observables that proxy for the information content stemming from the Fed. Third, the volume around FOMC announcements varies substantially across the term-structure of Eurodollar futures, particularly when forward guidance becomes an important policy tool.

This motivates the development of a new methodology that can flexibly adapt to the heterogeneity across announcements. However, the theory already proposes a relevant proxy for the amount of information: volume. Volume naturally captures the incentives of agents to trade and the literature surveyed in appendix A suggests a tight connection between volume, volatility and the informativeness of prices. Building on these facts, I develop the Volume-Based Surprise methodology. The approach determines announcement-specific window lengths and asset weightings using observable trading volume dynamics.

The Volume-based Surprise (VBS) is defined as

$$s^{VBS}_{m,x=\overline{x}_m+10} = \Lambda_m(f_{m,t+\overline{x}_m} - f_{m,t-10})$$

where:

- $\overline{x}_m$ is the announcement-specific upper window bound determined by volume normalization
- Λ_m represents announcement-specific loadings based on relative trading volume across contracts
- The lower window bound is fixed at 10 minutes before the announcement following convention

The underlying idea is to create a baseline of normal expected trading volume that would prevail in the Eurodollar market absent the FOMC announcement. This baseline is then compared to actual trading volume observed around the announcement. The window length is defined as the point where trading volume returns to the normal range.

Let $V_{m,t} = \sum_{c=1}^{14} V_{m,t,c}$ denote aggregate trading volume across Eurodollar contracts in minute t on FOMC announcement day m. The set of Eurodollar contracts includes the first twelve quarterly Eurodollar contracts and two monthly serial contracts, which in total capture interest rate expectations over the next three years, consistent with the maximum horizon of the FOMC's projection in the dot plot.

The idea is to find a $V^{\text{Normal}}_{m,t}$ which the realized volume $V_{m,t}$ can be compared to. Therefore, I estimate the expected volume distribution from the past 21 trading days for each announcement day m. This estimation window is sufficiently long to provide a robust estimate of normal volume patterns while being short enough to capture recent market conditions and seasonality effects. In addition, it avoids contamination from previous scheduled FOMC announcements, which typically occur every six weeks. Similar to the empirical analysis in Section 3, I bootstrap the average one-minute volume in a given 5-minute buckets t^{5M}.

I use the cluster bootstrap approach of Rao and Wu (1988), clustering by day to preserve the intraday correlation structure. Generally, the normal expected volume distribution could be estimated via OLS with clustered standard errors at the day level. However, the presence of periods with zero volume can potentially bias the estimates downwards, which the non-parametric bootstrap approach avoids (Davison and Hinkley, 1997).

To reduce noise, I smooth the one-minute volume by taking a 5-minute moving average. I then evaluate the smoothed volume against the 99.5 percentile of the normal volume distribution $V^{\text{Normal},0.995}_{m,t}$. I then define the upper window bound $\overline{x}_m$ as the minute where

$$V_{m,t} \leq V^{\text{Normal},0.995}_{m,t}$$

for the first time after the announcement, where $V^{\text{Normal},0.995}_{m,t}$ is the 99.5 percentile of the normal volume distribution.

For announcements with press conferences, I check for renewed abnormal volume during the conference period. If there exists $t_0 \in [t_{PC}, t_{PC}+75]$ such that for any 10-minute window $[t_0, t_0+10]$, $V^{5M}_{m,t} > V^{\text{Normal},0.995}_{m,t}$, then I restart the search for $\overline{x}_m$ from t_0.

Finally, I determine the loadings Λ_m based on the relative share of total volume each contract contributes during the announcement window $[t-10, t+\overline{x}_m]$:

$$\lambda_{m,c} = \frac{\sum_{h=t-10}^{t+\overline{x}_m} V_{m,h,c}}{\sum_{c=1}^{14} \sum_{h=t-10}^{t+\overline{x}_m} V_{m,h,c}}$$

where c indexes the twelve quarterly and two monthly serial Eurodollar contracts.

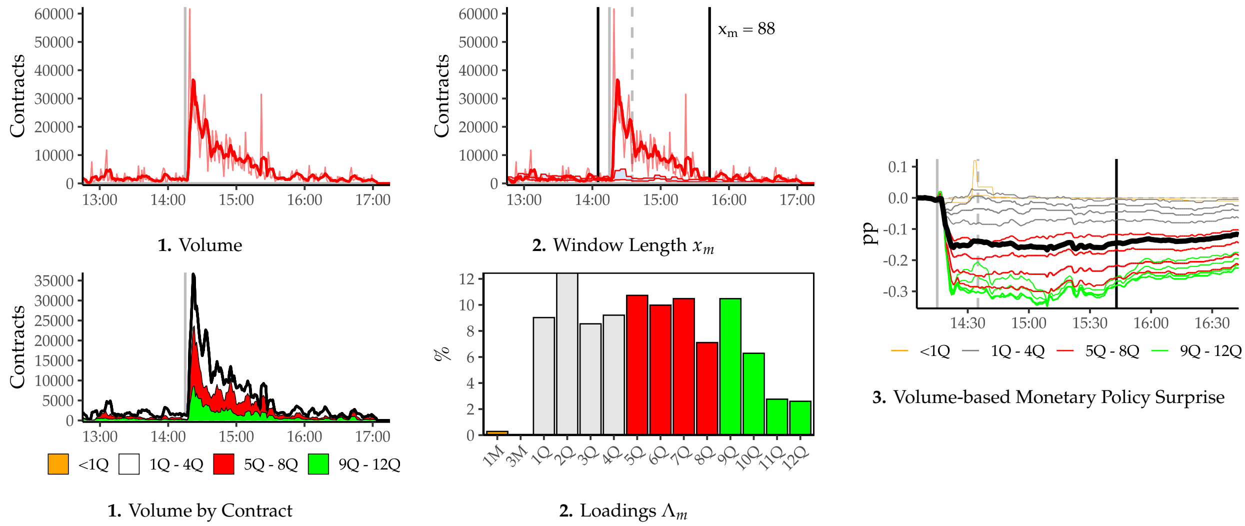
Intuitively, contracts with higher trading volume during the announcement window receive greater weight in the surprise calculation. This approach allows the surprise measure to adapt to changing market conditions and communication strategies over time. It flexibly includes more contracts if they become more relevant over time, e.g. due to changes in the FOMC's communication strategy. If an asset is not traded at all during the announcement window, $\lambda_{m,c} = 0$. Therefore, only true high-frequency surprises are captured.

There is no dependence across time since the loadings are determined solely by volume during the announcement window and not estimated from historical data. The expected trading volume is based on a sample of 21 days prior to the announcement, which is specific for each announcement and can be calculated prior to the announcement. This allows for the determination of the window length, loadings, and resulting surprise measure in real-time as highlighted in figure 4.

Figure 4 illustrates the construction of the volume-based surprise using the FOMC announcement on August 9, 2011 as an example. The Federal Reserve announced that economic conditions are "likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013" (Board of Governors of the Federal Reserve System, 2011). This leads to a substantial increase in trading volume that persists for 88 minutes after the announcement, as shown in panel 1. Panel 2 adds the 99% bootstrapped confidence interval of expected trading volume shown in blue. The black vertical lines indicate the bounds of the announcement-specific event window. The bottom row shows how the loadings Λ_m are determined as the relative share of each contract's volume to the total volume over the event window. The resulting volume-based monetary policy surprise is shown in panel 3 (right), which is calculated as a weighted sum of volume-weighted price changes across contracts during the announcement window using the loadings from panel 2.

In principle, approaches based on price volatility could be used instead of volume. Figure 1 documents the similar pattern over the FOMC announcement day, as documented as well in Fleming and Remolona (1999). There are two main reasons why I focus on volume. Volatility is unobservable and would need to be estimated or approximated, which introduces additional noise and estimation risk. In addition, the Eurodollar options market is not as liquid as the futures or equities market, making it difficult to obtain estimates of implied volatility. Second, it is problematic to estimate realized volatility for contracts with low trading volume, which is often the case for longer-dated Eurodollar contracts. In addition, it aggregating price volatility and adequately weighing the contracts is not straightforward. Therefore, this paper focuses

Figure 4: Illustration: FOMC Announcement on August 09, 2011



The figure illustrates how the volume-based surprise measure is constructed using the FOMC announcement on August 9, 2011 as an example. The first row (top left) shows 1-minute volume in light red and the 5-minute moving average in dark red. The figure in the second column adds the expected trading volume from the 21 prior trading days. The window length x_m is determined as the first minute after the announcement where volume returns to normal levels, the solid black lines denote the window lower $\underline{x} = -10$ and upper bound $\overline{x_m}$ respectively The bottom left panel shows the volume by contract during the announcement window. The bottom middle panel shows the loadings Λ_m as the relative share of each contract of total volume over the event window. Panel 3 (right) shows the resulting volume-based monetary policy surprise, which is calculated as a weighted sum of volume-weighted price changes across contracts during the announcement window using the loadings from panel 2.

on volume as the primary metric for determining window lengths and loadings.

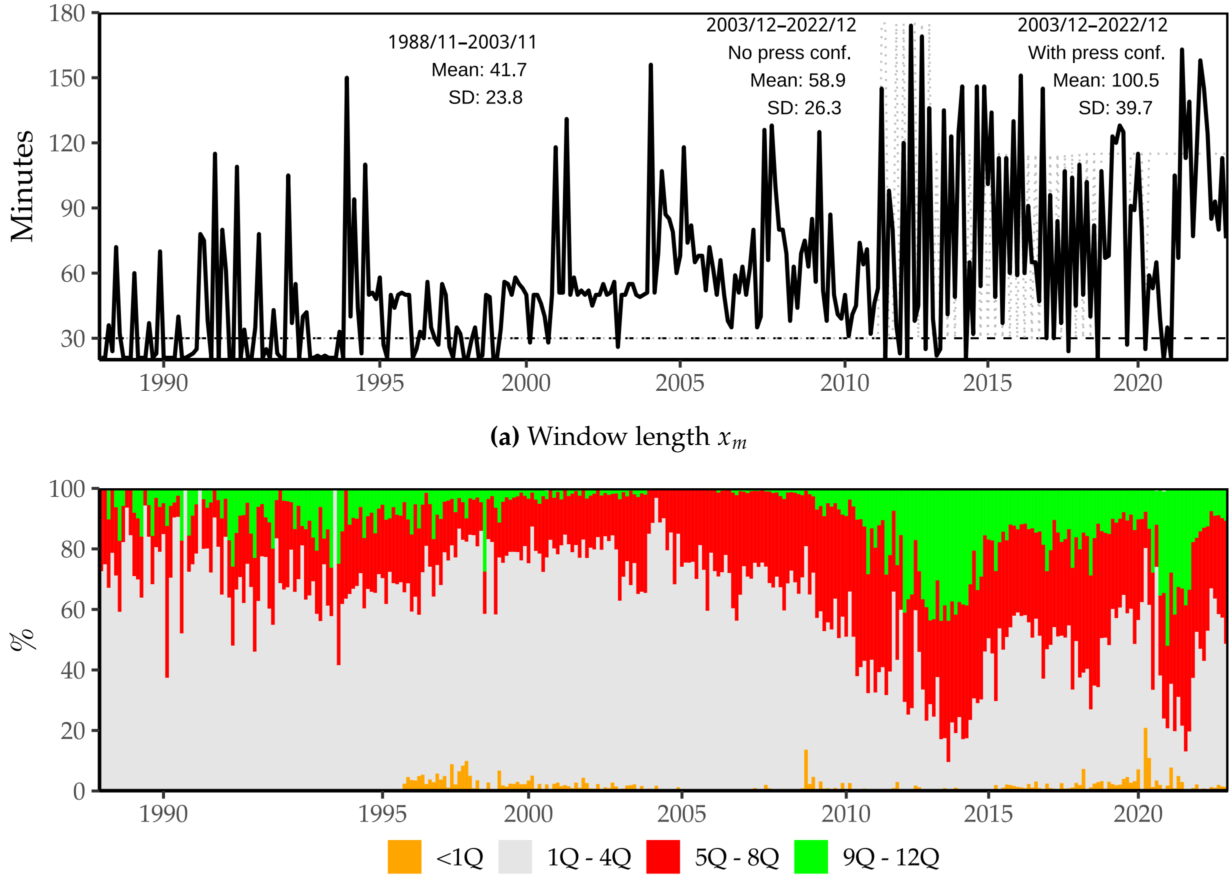
3.1 Announcement-Specific Window Lengths and Loadings

Panel (a) of figure 5 displays the time series of announcement-specific window lengths x_m throughout the sample period. Several distinct patterns emerge that reflect the evolution of FOMC communication and market structure. During the pre-electronic trading era (1988-2003), window lengths averaged 42 minutes with substantial variation around individual announcements. Some windows are very short, extending to just 20 minutes, while others extend up to 150 minutes such as the first press release in February 1994 that caught markets by surprise. Since 1999 the FOMC provides a statement after each meeting which raises the window length commonly beyond 30 minutes, often hitting 55 minutes due to the constraint of the Eurodollar futures pit closing at 3pm ET.

The introduction of electronic trading in December 2003 marked a structural shift toward longer windows, with averages increasing to 59 minutes for announcements without press conferences. This is particularly highlighted by the large windows during 2004, when the federal funds rate was set at 1% and markets were uncertain about the path of future rate hikes and during the global financial crisis in 2008-2009. During the zero-lower bound period, on days without press conferences window length are generally quite small.

The period from December 2003 to November 2018 when no press conferences were held provides a clean setting to study the determinants of window lengths. Window lengths are not bound by the end of the pit trading at 3pm ET and are not influenced by the additional information provided during press conferences. In appendix C.2, I show that the window length is positively correlated with a text-based

Figure 5: Volume-Based Surprise



(a) Window length x_m

(b) Loadings Λ_m

Panel (a) shows the announcement-specific window lengths $\overline{x}_m$. Panel (b) shows the announcement-specific loadings Λ_m aggregated into four maturity buckets: <1Q (two monthly serials), 1Q-4Q (3-12 months), 5Q-8Q (13-24 months) and 9Q-12Q (25-36 months).

measure of statement dissimilarity between the current and preceeding statement. This measure can account for 30% of the variation in window lengths, suggesting that more sizable new information leads to longer windows.

The most dramatic changes in window lengths occur with the introduction of regular press conferences in 2011. For announcements accompanied by press conferences, average window lengths extend to 100 minutes. These extended windows during press conference periods provide direct evidence that press conferences contain important information(Gómez-Cram and Grotteria, 2022). Since 2021, the window lengths always extend to at least 67 minutes which highlights the prominent role of press conferences in the current communication strategy of the FOMC.

Panel (b) illustrates the evolution of volume-based loadings over time. The time-varying nature of these weights reveals fundamental changes in how markets process and respond to FOMC information across different policy regimes. For illustrative purposes, I aggregate the loadings into four maturity buckets: <1Q (two monthly serials), 1Q-4Q (3-12 months), 5Q-8Q (13-24 months) and 9Q-12Q (25-36 months).

During 1988 to 2003, volume was heavily concentrated in the first four quarterly Eurodollar contracts (1Q-4Q), which is entirely consistent with the construction of conventional 30M-PC measures. These contracts, covering expectations for the next 12 months, captured the primary focus of market attention when monetary policy operated primarily through current rate adjustments with limited forward guidance.

However, starting in 2003 volume gradually shifted toward longer-maturity contracts that accelerated dramatically during the zero lower bound period. At the onset of the zero lower bound in late 2008, the share of contracts in the 25-36 month maturity bucket (9Q-12Q) began increasing substantially. By 2013, during the peak of the Fed's forward guidance communications, these longer-maturity contracts accounted for over 40% of total trading volume, while the traditional 1Q-4Q contracts that form the basis of conventional 30M-PC measures fell below 20% of total volume.

This shift reflects a fundamental change in the information content of FOMC communications. As the Fed increasingly relied on forward guidance about the future path of policy rates, market participants naturally focused their trading activity on contracts whose payoffs were most sensitive to this information. The contracts with maturities extending 25-36 months ahead became the primary vehicle for expressing views about the timing and pace of policy normalization.

Importantly, even after policy normalization began, longer-maturity contracts maintained elevated importance relative to the pre-crisis period. Throughout the remainder of the sample, the share of the 25-36 month contracts remained at least 10% of total volume, suggesting a permanent shift in the market's focus toward longer-term policy expectations. This persistent change likely reflects both the Fed's continued use of forward guidance as a policy tool and market participants' heightened awareness of the importance of policy path expectations.

The evolution of loadings also reveals important heterogeneity across individual announcements. During periods of significant policy communication, volume concentration can shift dramatically toward specific maturity buckets. For instance, announcements containing explicit date-based forward guidance (such as the August 2011 commitment to keep rates low "at least through mid-2013") show particularly high concentration in contracts maturing around the specified dates. In appendix C.5, I put the observed window lengths, loadings and resulting volume-based surprise around specific announcements into their historical context to illustrate these dynamics.

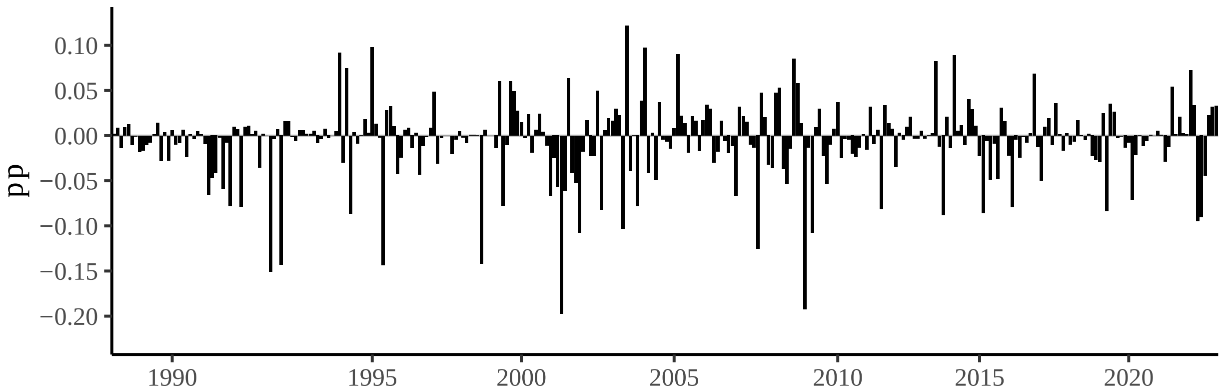
3.2 Comparison with Existing Measures

The Volume-based Monetary Policy Surprise (VBS) is displayed in panel (a) of figure 3.2. It is rescaled to have a unit effect on the daily 1-year daily Treasury yield change for ease of comparison with existing measures. The VBS shows substantial variation across announcements, with a standard deviation of 4.1 basis points across the full sample.

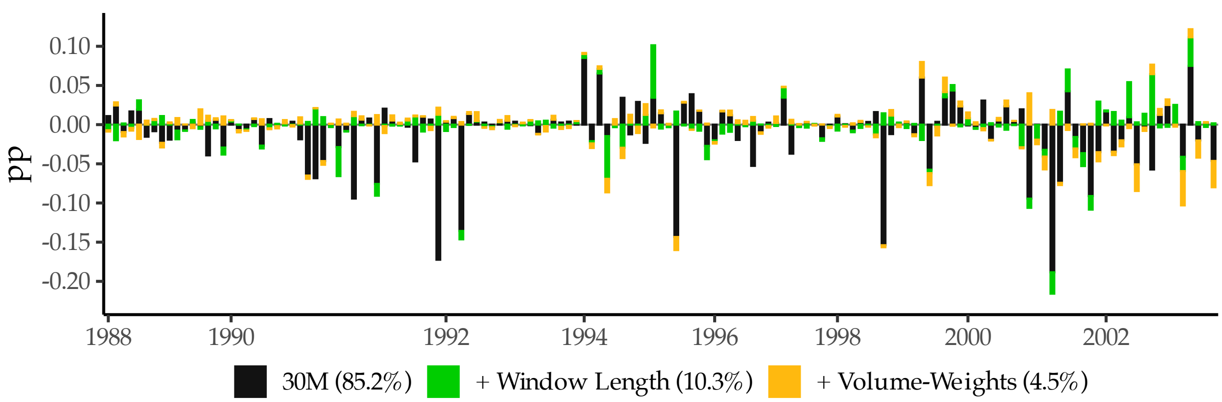
To put the VBS in context, I decompose it into three distinct components across two sample periods. These sample periods reflect major changes as documented in the previous section. Between 1988/11-2003/11 contracts were not traded electronically, windows lengths are substantially only slightly longer then 30 minutes and trading is concentrated in the first four Eurodollar futures contracts, the same contracts commonly used in the monetary policy surprise literature. Between 2003/12-2022/12, electronic trading becomes

Figure 6: Volume-Based Surprise

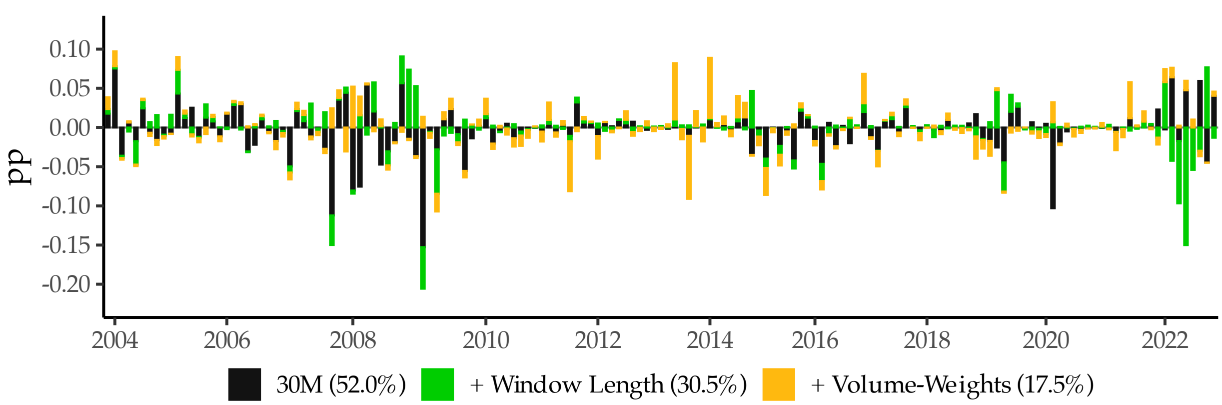
(a) $\Lambda_m(f_{m,t+\bar{x}_m} - f_{m,t-10})$



(b) Decomposition: 1988/11-2003/11



(c) Decomposition: 2003/12-2022/12



The figure shows the decomposition of the volume-based surprise into three components. The first component is the 30-minute 30M-PC surprise, which is the standard measure of monetary policy surprises. The second component is the volume-based surprise that is explained by the window length (WL) and the third component is the volume-based surprise that is explained by the volume-weighting (VW). The window length component is the residuals of a regression of the first principle component of the first four Eurodollar futures with flexible window lengths x_m on the 30-minute 30M-PC surprise. The volume-weighting component is the residual variation in the volume-based surprise after regressing it on the 30M-PC and the WL component. The decomposition is implemented separately between 1988/11 - 2003/11 () and 2003/12 - 2022/12.

the dominant mode of trading, window lengths become substantially as the Federal Reserve introduces press conferences and the volume-based loadings move towards longer-dated interest rate futures. The decomposition proceeds as follows.

First, I identify the component of VBS variation that can be explained by the conventional 30-minute 30M-PC through a simple regression. The R-squared from this regression quantifies how much of the volume-based surprise is captured by the 30M-PC. Second, I construct a "window length component" by estimating the first principal component of the first four Eurodollar futures using the announcement specific volume-based windows x_m, then regressing it on the 30-minute 30M-PC and taking the residuals. This isolates the additional information captured purely by extending window lengths. Third, the "volume-weighting component" represents the residual variation in the VBS after accounting for both the 30M-PC and window length components.

This decomposition strategy allows me to separately identify: (1) information that conventional measures already capture, (2) information that could be captured by conventional measures if they used longer windows, and (3) information that requires both longer windows and adaptive asset weightings to capture.

Figure 6, Panel (b) reveals that during the early sample period, the relationship between volume-based and conventional measures was remarkably close. The conventional 30-minute first principal component (30M-PC) explained 85% of the variation in the VBS, with the window length component contributing only 10% additional explanatory power and volume weighting accounting for a mere 5% of variation.

The later sample period reveals a transformation in the relationship between volume-based and conventional measures. Panel (c) of Figure 6 shows that only 52% of VBS variation is explained by the conventional 30M-PC, representing a substantial decline in explanatory power. The window length component now accounts for 30% of VBS variation, while volume weighting contributes 18%.

This transformation reflects the fundamental changes in FOMC communication that occurred during this period. The introduction of regular press conferences and expanded use of forward guidance lead to a substantial information about the path of policy rates being revealed during longer windows and at longer horizons typically considered in conventional monetary policy surprises.

The strong correspondence between VBS and conventional measures during the early period confirms that when monetary policy operated primarily through current rate adjustments with short-term forward guidance, the assumptions made in the literature match those determined by the market. The minimal contribution of extended windows explains why Gürkaynak et al. (2005) found little difference between 30-minute and 60-minute windows during their sample period.

The volume-weighting component becomes particularly economically significant during specific policy episodes. During zero lower bound periods, this component captures substantial variation that generates no significant response in the 30M-PC, suggesting genuine policy surprises that conventional measures completely miss. Appendix C.3 shows that the volume-weighting component is closely linked to changes in the Fed's dot plot projections, which provide explicit forward guidance about the future path of policy rates. The forecast error between the market's median expectation, measured by the Primary Dealer Survey, and the Fed's dot plot median projection at the longest horizon, typically 2-3 years in the future, is significantly correlated with the volume-weighting component.

Similarly, the window length component gains particular importance during the recent tightening cycle starting in 2022, where press conference communications often provide crucial additional information about policy intentions that unfolds over extended periods. Fed Chair Powell's communications during press conferences frequently clarify or modify the implications of the formal policy statement, information that is only captured through extended measurement windows.

4 Financial Markets Evidence

Having established the Volume-Based Monetary Policy Surprise (VBS) methodology and documented its empirical properties, I now evaluate its performance in capturing monetary policy effects on financial markets. I follow the common event study methodology which analyzes asset prices changes in response to monetary policy surprises. Following Nakamura and Steinsson (2018), I focus on scheduled FOMC announcements and drop the Global Financial Crisis period (2008/07 to 2009/06) and March to June 2020, when the dash-for-cash crisis unfolded. I standardize all surprises to unit variance in the respective sample, to allow for direct comparison of the economic magnitude of the effects across different surprise measures. The coefficients can therefore be interpreted as the asset price response to a one-standard-deviation surprise in the respective sample.

Treasury Market

Understanding how monetary policy surprises affect Treasury yields is central to understanding monetary policy transmission to the broader economy. Treasury yields serve as benchmarks for mortgage rates, corporate bond yields, and other borrowing costs, making them a key channel through which monetary policy affects households and firms. A general finding is that monetary policy surprises have a large positive effect on Treasury yields over the entire yield curve (Kuttner, 2001; Nakamura and Steinsson, 2018; Hanson and Stein, 2015). Treasury yields can be decomposed into real yields, obtained from TIPS securities, and breakeven inflation, the compensation an investor requires for holding nominal bonds instead of real bonds. Generally, event studies find that monetary policy affects the real yield and forward curves but have no impact on breakeven inflation (Hanson and Stein, 2015; Nakamura and Steinsson, 2018).

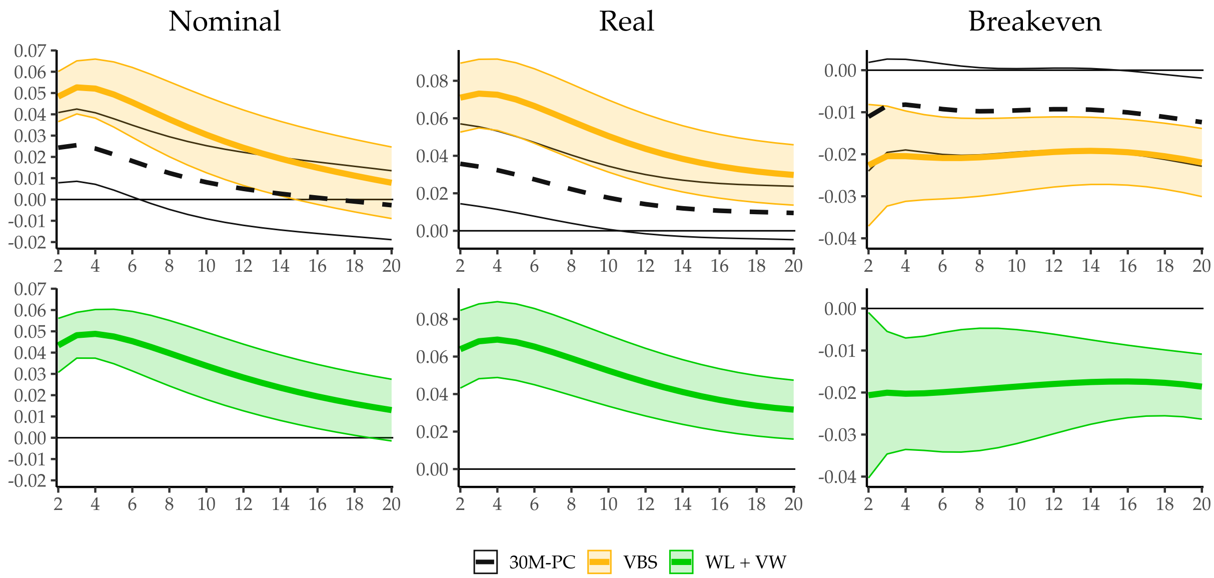
The objective of this section is to study two questions. First, how do monetary policy surprises affect Treasury yields across different maturities? Second, does the Volume-based Surprise (VBS) capture different aspects of monetary policy than conventional measures, and if so, what economic mechanisms explain these differences?

To answer these questions, I estimate announcement-level regressions of the form:

$$\Delta y_m^h = \alpha^h + \beta^h \cdot s_m + \epsilon_m^h$$

where Δy_m^h is the yield change of a Treasury security with maturity h around announcement m, and s_m is the respective monetary policy surprise. Data for real and breakeven yields come from Gürkaynak et al. (2010),

Figure 7: Treasury Market - Yield Curves



The figure shows the 2-day change, from the day prior to the FOMC announcement to the day after, in the yield of a Treasury security with maturity h (in pp) to the respective 1SD surprise measure

$$\Delta y_m^h = \alpha^h + \beta^h \cdot s_m + \epsilon_m^h.$$

The surprises are the first principal component of 30-minute price changes (30M-PC) (Nakamura and Steinsson, 2018) and the Volume-based Monetary Policy Surprise (VBS). The sample includes all scheduled FOMC announcements from December 2003 to December 2022 excluding the Global Financial Crisis (2008/07 to 2009/06) and March to June 2020. The underlying dataset for real and breakeven yields is Gürkaynak et al. (2010) and for nominal yields (Gürkaynak et al., 2007). The shaded areas represent 95% confidence intervals based on heteroskedasticity-robust (HC3) standard errors.

while nominal yield data are from (Gürkaynak et al., 2007). Since the underlying yields in (Gürkaynak et al., 2010) are based on quoted yields at 15:00 ET on each trading day, I follow Hanson and Stein (2015) and measure the yield change over a 2-day window. The flexible window lengths of the Volume-based Monetary Policy Surprise (VBS) do sometimes end later than 15:00 ET. A 2-day window therefore ensures that dealers have sufficient time to fully incorporate the information from the announcement into prices. The regressions are separately estimated for each maturity h and surprise measure.

My main empirical finding is that the VBS has substantially larger effects on Treasury yields than conventional measures across the entire yield curve. Figure 8 shows these results. A contractionary one-standard-deviation VBS surprise increases nominal yields by around 5 basis points at the peak, with effects remaining statistically significant out to 14-year maturities. In contrast, the conventional 30-minute price change (30M-PC) measure shows a peak response of only 2.5 basis points and becomes statistically insignificant for maturities beyond 6 years.

To put the nominal yield curve results into perspective, a contractionary VBS which increases the 2-year Treasury yield by 1pp leads to a 0.6 percentage point increase in the 10-year yield, while the 30M-PC leads to only a 0.3 percentage point increase. At the medium end of the curve, the VBS leads to a peak effect of slightly above 2pp at the 4-year maturity, while the 30M-PC peak at around 0.87pp at the 3-year maturity. Nakamura and Steinsson (2018) find a 0.34 increase at the 10-year maturity relative to a 1 pp increase in the 2-

year yield which is consistent with the 30M-PC response over a slightly different sample. Therefore, the VBS leads to a substantially larger shift across the entire nominal yield curve than conventional measures.

The decomposition into real and breakeven yields provides insight into the economic mechanisms driving these differences. A contractionary VBS induces an upward shift across the entire real yield curve, with a peak response of around 7 basis points and statistically significant effects even at the 20-year maturity. This pattern suggests that monetary policy surprises have persistent effects on real interest rates. Simultaneously, breakeven inflation also responds with a level shift of around 2 basis points across the entire term structure. This negative response of breakeven inflation—which combines investors' inflation expectations and inflation risk premia—explains why nominal yields show weaker responses than real yields across the curve.

This impact on breakeven inflation is a novel finding. Previous event studies have generally found no effect of monetary policy on breakeven inflation (Hanson and Stein, 2015; Nakamura and Steinsson, 2018) which in turn implies that movements in the nominal yield curve are entirely driven by changes in real yields. Interestingly, the pattern documented here for the 30M-PC is similar but with one substantial difference. The 30M-PC only shows a significant at the very long end of the curve while the VBS shows a significant and sizable impact on breakeven inflation at the short end of the curve. At the long end, risk premia are likely to dominate the response, as monetary policy is unlikely to affect very long real interest rates or inflation expectations. However, it is difficult to precisely identify the channels through which monetary policy affects breakeven inflation and real yields without an explicit term structure model (Abrahams et al., 2016)

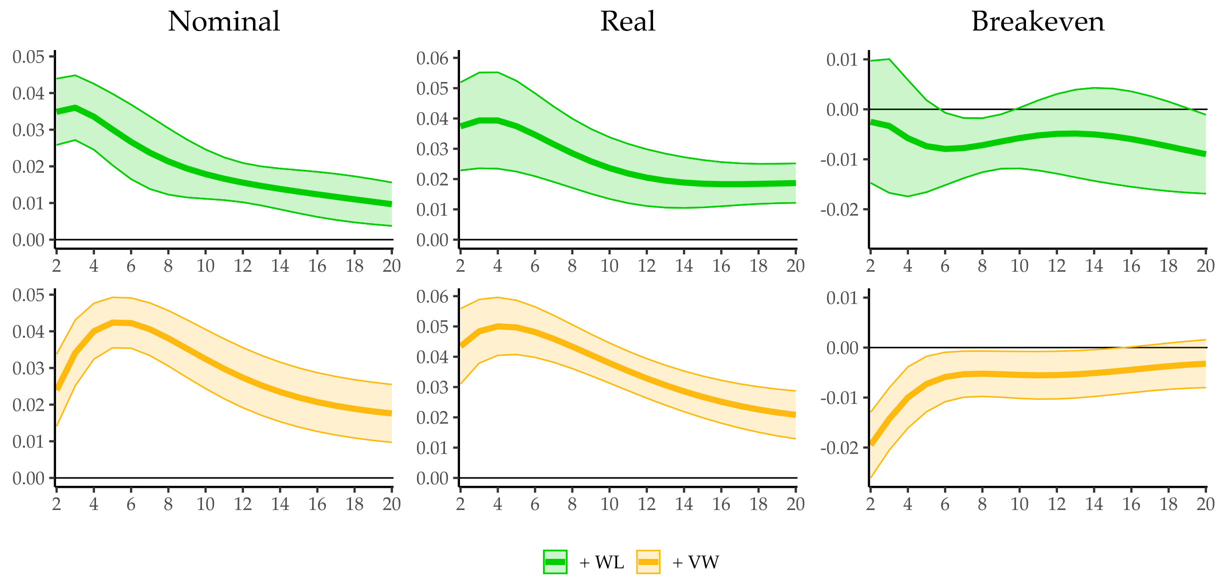
To better understand what drives the difference between the VBS and the 30M-PC, I use the decomposition into the window length and volume-weighting component from section 3.2. The window length component captures the difference in surprises due to longer market processing times and the press conferences, while volume-weighting measures the effects of longer-dated forward guidance. Figure 8 shows that these components have distinct effects on the yield curve.

The window-length component induces a persistent upward shift in real yields, with a peak effect of 4 basis points and statistically significant effects out to 20-year maturities which stay elevated at around 2.5 basis points. This implies that the slope of the real yield curve,forward rates, stay elevated even at long horizons. Similarly, the window-length component has only a modest effect on breakeven inflation at the short-end of the curve, but later turns negative at intermediate and long maturities. These responses are consistent with the interpretation that the window-length component affects bond and inflation risk premia, particularly at longer horizons.

In contrast, the volume-weighting component has a more pronounced effect on both real yields and breakeven inflation at the short-to-medium end of the curve. These effects decay substantially at longer maturities, suggesting that forward rates turn negligible at long horizons. Appendix E confirms that this is indeed the case with real forward rates and breakeven inflation forward rates becoming insignificant after 10 years.

These patterns suggest that the volume-weighting component captures aspects of monetary policy that affect expectations about real rates and inflation over the medium-term. With the interpretation that

Figure 8: Yield Curves - Surprise Decomposition



The figure shows the 2-day change, from the day prior to the FOMC announcement to the day after, in the yield of a Treasury security with maturity h (in pp) to the respective 1SD surprise measure

$$\Delta y_m^h = \alpha^h + \beta^h \cdot s_m + \epsilon_m^h.$$

Here, s_m denotes the two components of the Volume-based Surprises: the window length component and the volume-weighting component. These components measure the difference in the VBS to the 30-minute principal component surprise (30M-PC) (Nakamura and Steinsson, 2018), due to announcement-specific window lengths and announcement-specific loadings respectively. The sample includes all scheduled FOMC announcements from December 2003 to December 2022 excluding the Global Financial Crisis (2008/07 to 2009/06) and March to June 2020. The underlying dataset for real and breakeven yields is Gürkaynak et al. (2010) and for nominal yields (Gürkaynak et al., 2007). The shaded areas represent 95% confidence intervals based on heteroskedasticity-robust (HC3) standard errors.

the volume-weighting component captures longer-dated forward guidance and the Fed's Dot Plot, these findings are consistent with the view that forward guidance has a sizable impact on medium-term real rate and inflation expectations.

Table 1 presents additional evidence on how these patterns vary across sample periods and shows how daily changes in the 1-year and 10-year Treasury yields respond to monetary policy surprises.

During the early sample period, both the VBS and conventional 30M-PC perform similarly, with comparable coefficient estimates and explanatory power. This finding validates the methodology while confirming that conventional approaches were adequate during the era of straightforward rate-based monetary policy. However, the later period reveals substantial differences between the measures. For 10-year Treasury yields, a one-standard-deviation contractionary VBS surprise increases yields by 3.4 basis points, compared to only 0.09 basis points for the conventional 30M-PC. The explanatory power also increases substantially, with the R-squared rising from 1.4% using the 30M-PC to 29% using the VBS. Even for the 1-year Treasury yield, the VBS has an explanatory power of 42% whereas the 30M-PC explanatory power drops to 15% from 47% in the earlier sample period.

In sum, these results suggest that the VBS captures economically important aspects of monetary policy

Table 1: Treasury Market - Event Study Results

	1988/11 - 2003/11 (n= 141)			2003/12 - 2022/12 (n= 142)		
	30M-PC	VBS	WL + VW	30M-PC	VBS	WL + VW
Dep Var: 1Y Treasury						
Estimate	0.051***	0.049***	0.007	0.016***	0.026***	0.021***
SE	(0.004)	(0.005)	(0.007)	(0.006)	(0.004)	(0.006)
R^2	0.467	0.420	0.001	0.153	0.426	0.270
Dep Var: 2Y Treasury						
Estimate	0.050***	0.052***	0.016**	0.027***	0.050***	0.042***
SE	(0.004)	(0.004)	(0.006)	(0.008)	(0.005)	(0.005)
R^2	0.419	0.444	0.036	0.185	0.627	0.453
Dep Var: 10Y Treasury						
Estimate	0.027***	0.031***	0.015**	0.009	0.034***	0.037***
SE	(0.004)	(0.004)	(0.007)	(0.007)	(0.006)	(0.004)
R^2	0.189	0.243	0.053	0.014	0.291	0.360

This table reports the estimated coefficients of a regression selected Treasury market yields on the respective monetary policy surprise. All dependent variables stem from the Federal Reserve H.15 report and can be found here. The sample includes all scheduled FOMC announcements from December 2003 to December 2022 excluding the Global Financial Crisis (2008/07 to 2009/06) and March to June 2020. The surprises are the first principal component of 30-minute price changes (30M-PC) (Nakamura and Steinsson, 2018), the Volume-based Monetary Policy Surprise (VBS) and sum of the window length and volume-weighting of the VBS (WL + VW) Reported standard errors are heteroskedasticity-robust (HC3) and the stars indicate significance at the 10%, 5% and 1% level.

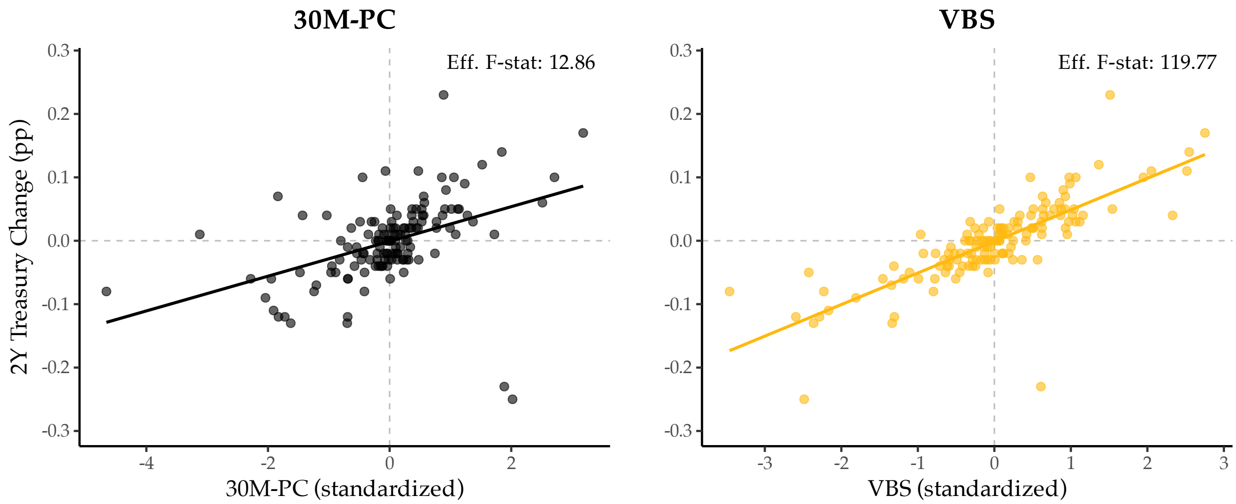
that conventional measures miss, operating through both expectations and term premia. In particular, medium-term inflation expectation are substantially affected by the volume-weighting component that captures longer-dated forward guidance. This is consistent with the interpretation of the volume-weighting component capturing particularly longer-dated forward guidance, which is likely to affect expectations about real rates and inflation over the medium-term.

Economic Magnitudes and Instrument Strength

It is common to scale monetary policy shocks to a 1 percentage point (pp) increase in the 1-year yield (Nakamura and Steinsson, 2018; Bauer and Swanson, 2022) which allows a more intuitive interpretation of the economic magnitude of the effects at the cost of losing the comparability of the surprise measures as they will not share the same scale. This requires caution when interpreting the coefficients rescaled in such a manner as this is akin to running a first-stage regression of the 1-year yield on the respective surprise measure and therefore requires that the monetary policy surprise is a strong instrument for daily yield changes. To investigate this, I plot the first-stage relationship between the 2-year Treasury yield and the respective surprise measure in Figure 9. I use the 2-year yield as a reference instead where both surprises have their peak impact (see Table 1). A one-standard-deviation VBS surprise leads to a 5bp increase in the daily 2-year Treasury yield (see Table 1) whereas the 30M-PC measure leads to a 2.7bp increase.

If I were to instrument changes in the two-year yield using the 30M-PC—where its effect on the term structure is strongest—the identification would nevertheless be weak. The effective F-statistic (Olea and Pflueger, 2013) for this specification is 12.86, which falls well below the conventional 10 percent bias critical

Figure 9: Instrument Strength: 2-Year Yield on Monetary Policy Surprises



The figure shows the daily change in the 2-year Treasury yield (in pp) on the y-axis and the respective 1SD surprise measure on the x-axis. The sample includes all scheduled FOMC announcement days between December 2003 and December 2022. I exclude all announcements during the Global Financial Crisis (2007-2009) and March to June 2020. The effective F-statistic (Olea and Pflueger, 2013) is reported for both specifications. The critical values for 10% bias are 23.1 and 37.4 for 5% bias respectively.

value of 23.1. This implies that even at the maturity where the 30M-PC has its greatest explanatory power, it remains a weak instrument for daily yield changes. By contrast, the VBS surprise measure yields an effective F-statistic of 119.77, comfortably above all critical thresholds.

Equity Market

The impact of monetary policy on equity markets is a key channel through which policy affects household wealth and corporate investment decisions. Moreover, understanding how stock markets respond to monetary policy provides insight into how investors interpret and incorporate policy communications into their expectations about future economic conditions and discount rates.

To examine these responses, I estimate announcement-level regressions of the form:

$$y_m = \alpha + \beta \cdot s_m + \epsilon_m$$

where y_m represents the change in asset y around announcement m, and s_m is the respective monetary policy surprise.

My main empirical finding is that equity markets have become increasingly sensitive to monetary policy communications over time, and the VBS captures this sensitivity substantially better than conventional measures. Table 2 presents these results. The first row shows results for intraday S&P 500 futures returns measured over the same window as the surprise, while the second row shows results for the daily SP500 return.

During the early sample period, both surprise measures suggest that a contractionary policy shock reduces the daily stock return by around 0.23% (30M-PC) and 0.21% (VBS). Rescaled such that each surprises increase the daily 2-year Treasury yield by 1pp, this amounts to an decrease of -4.5 percent for the 30M-PC and -4.1

Table 2: Equity Market - Event Study Results

	1988/11 - 2003/11 (n= 141)			2003/12 - 2022/12 (n= 142)		
	30M-PC	VBS	WL + VW	30M-PC	VBS	WL + VW
Dep Var: SP500 Future (Intraday)						
Estimate	-0.217***	-0.172***	0.006	-0.298***	-0.435***	-0.321***
SE	(0.035)	(0.050)	(0.054)	(0.033)	(0.060)	(0.096)
R^2	0.251	0.139	-0.007	0.401	0.317	0.169
Dep Var: SP500 Total Return (Daily)						
Estimate	-0.225***	-0.213***	-0.027	-0.218	-0.433***	-0.388***
SE	(0.070)	(0.079)	(0.083)	(0.135)	(0.110)	(0.121)
R^2	0.050	0.044	-0.006	0.030	0.141	0.112

This table reports the estimated coefficients of a regression of the stock market return on the respective monetary policy surprise. The S&P Future Return is calculated from the price of the E-Mini (Ticker: ES) contract after 1998 and the broad SP Future (Ticker: SP) in earlier sample periods. It is measured over the same window as the surprise. In the first column, the window is the 30-minute window, while in the second and third column, the window is the flexible window length. The daily CRSP value-weighted stock market return is measured on the day of the announcement. Reported standard errors are heteroskedasticity-robust (HC3) and the stars indicate significance at the 10%, 5% and 1% level.

percent in the VBS.

However, the later period reveals substantial differences between the measures. The VBS implies that contractionary policy reduces daily stock prices by 0.44 percent, while the conventional 30M-PC suggests a 0.22 percent decline that is no longer statistically significant. The explanatory power differences are particularly dramatic: in the later sample period, the VBS explains 14 percent of daily stock return variation around FOMC announcements, compared to just 3 percent for conventional measures.

In economic terms, a one-standard-deviation VBS surprise, which increases the daily 2-year Treasury yield by 1pp during the same sample, leads to a 8.71 percent decline in daily stock prices, compared to a 7.95 percent decline for the 30M-PC. The scale of the coefficients is determined by the relative impact of the surprises on the 2-year yield, which is twice as large at 5.0bp for the VBS and 2.7bp for the 30M-PC. These effects should be interpreted with caution for the 30M-PC as it is a weak instrument for daily yield changes (see above).

For intraday returns, the explanatory power is higher for both measures, which is not surprising given that the windows are substantially shorter. This is one of the motivating facts for using tight measurement windows. However, the VBS achieves relatively similar explanatory power despite using substantially longer windows, suggesting that the additional information captured by extending the window and volume-weighting offsets the noise from using longer measurement periods.

These findings suggest that equity markets have become increasingly responsive to the Federal Reserve's communications over time, with monetary policy surprises now explaining a substantially larger share of stock market variation around announcements. Understanding what drives these improvements is important for interpreting how monetary policy affects asset prices and the broader economy.

The results so far demonstrate that the VBS explains more of the variation in both Treasury and equity markets, but they do not reveal which specific innovations drive these improvements. To understand the

Table 3: Event Study Results - Surprise Decomposition

	PC + No PC			No PC		
Dep Var:	1Y	10Y	SP500	1Y	10Y	SP500
Constant	-0.006**	-0.002	0.195**	-0.002	0.004	0.112
	(0.002)	(0.004)	(0.091)	(0.004)	(0.006)	(0.141)
30M-PC	0.018***	0.007	-0.229*	0.014**	0.004	-0.322
	(0.004)	(0.005)	(0.128)	(0.006)	(0.006)	(0.198)
+ WL	0.025***	0.022***	-0.343**	0.019***	0.019***	-0.042
	(0.006)	(0.004)	(0.133)	(0.003)	(0.006)	(0.292)
+ VW	0.002	0.032***	-0.192	0.004	0.033***	-0.227
	(0.004)	(0.004)	(0.131)	(0.008)	(0.006)	(0.384)
R2 Adj.	0.555	0.406	0.140	0.463	0.331	0.098
Num.Obs.	142	142	142	80	80	80

Table reports the coefficients from the following regression

$$y_m = \alpha + \beta_1 \cdot \text{30M-PC}_m + \beta_2 \cdot \text{WL}_m + \beta_3 \cdot \text{VW}_m + \epsilon_m$$

where WL denotes the window length component and VW denotes the Volume-weighting component. Reported standard errors are heteroskedasticity-robust (HC3) and the stars indicate significance at the 10%, 5% and 1% level.

sources of improved explanatory power, I use the decomposition of the VBS from Section 3.2.

Specifically, I estimate regressions that include three components: the conventional 30M-PC, the window length extension component, and the volume-weighting component. This decomposition allows me to separately identify the contributions of extended processing times (window length) and the market's interpretation of forward guidance across different maturities (volume-weighting).

Table 3 reports these results. My main finding is that both components contribute to improved explanatory power, but their relative importance differs substantially across asset classes. For Treasury markets, both the window length and volume-weighting components are statistically significant and economically meaningful. The volume-weighting component is particularly important for longer-maturity Treasury securities, reflecting its ability to capture information from path-surprises embedded in longer-dated Eurodollar contracts.

For equity markets, the pattern is strikingly different. The improvements are driven primarily by the window length component rather than volume-weighting. To test whether press conferences drive these window length effects, I re-estimate the decomposition using only announcements without press conferences. For Treasury markets, both components remain statistically significant, suggesting that extended processing times reflect fundamental aspects of information incorporation rather than just press conference effects. For equity markets, however, the window length effects are substantially reduced in the absence of press conferences. This finding highlights that the stock market response rely heavily on the additional context that press conferences provide to fully interpret policy announcements, rather than simply requiring more time to process the formal policy statement itself. This is in line with Acosta et al. (2025) and Gómez-Cram and Grotteria (2022) who study the stock market response around FOMC press conferences.

5 Macroeconomic Evidence

Having documented the sizable increase in event study estimates of monetary policy effects on financial markets, I now turn to the broader macroeconomic implications. The analysis of high-frequency monetary policy surprises, pioneered by Gertler and Karadi (2015), has been influential in understanding the causal link of monetary policy on the economy. The monetary policy surprises can help to identify the structural monetary policy shock (Stock and Watson, 2018) and the impact of these shocks on the economy can be traced out using impulse response functions (IRFs).

There are two puzzling issues in the literature with high-frequency identification. The first point is that the estimated effects of monetary policy on inflation are small and insignificant (Gertler and Karadi, 2015; Ramey, 2016; Plagborg-Møller and Wolf, 2022) which runs counter to predictions of the standard macroeconomic models.

The second point, highlighted by Ramey (2016), is the choice of sample period. The IRFs of the economy to monetary policy shocks under various identification schemes are stronger in samples that include the 60s and 70s but importantly do not hold up well in later samples. Ramey argues that this is due to the fact that monetary policy is being conducted more systematically leading to less true surprises, making it more difficult to identify the effect of a monetary policy shock.

Motivated by the findings in the previous section, I investigate whether the VBS can help to resolve these two puzzles and if these results are in conflict with other solutions proposed in the literature.

5.1 Baseline VAR

The following analysis uses the same variable as in (Gertler and Karadi, 2015) consisting of the 1-year government bond yield (GS1), the excess bond premium (EBP) and output, measured by Industrial Production (IP), and inflation, measured by the CPI. The baseline results are a monthly Vectorautoregressive model (VAR) with lag length 12.

To identify the monetary policy shock, I follow the internal instrument approach (Plagborg-Møller and Wolf, 2021). The monetary policy surprise is included in the above VAR and ordered first. Similar timing assumptions are used in (Ramey, 2011; Jarociński and Karadi, 2020). The key advantage is that the impulse-response function to the monetary policy surprise are identified under non-invertibility of the VAR which is a common issue for these type of VARs (Plagborg-Møller and Wolf, 2022). While the external instruments approach (Mertens and Ravn, 2013) allows for a longer data sample then surprise availability, it requires invertibility of the VAR for the shocks to be identified.

Identification Let z_t be the instrument obtained by summing up the respective monetary policy surprise in a given month and let w_t be the stacked vector of macroeconomic variables. I estimate the following reduced-form VAR where $y_t = (z_t, w_t')'$

$$w_t = \mu + A(L)y_{t-1} + u_t$$

where $A(L)$ is a lag polynomial of order 12.

This requires the following two assumptions. First, the variables are driven by a set of structural shocks

$$w_t = \Theta(L)\epsilon_t, \quad \epsilon_t \sim N(0, I_{n_\epsilon}).$$

. Without loss of generality, the monetary policy shock is the first structural shock $\epsilon_{1,t}$ and the object of interest is the impulse response function of the macroeconomic variables to the monetary policy shock Θ_1.

Secondly, the exclusion restrictions that the instrument is correlated with the monetary policy shock but uncorrelated with all other structural shocks after adjusting for all past information

$$\text{Cov}\left(z_t, \varepsilon_{j,s} \mid \{z_\tau, w_\tau\}_{-\infty<\tau<t}\right) \neq 0 \quad \text{if and only if} \quad \text{both } j = 1 \text{ and } t = s.$$

(Plagborg-Møller and Wolf, 2021) show that under these two assumptions, the above VAR can be used to identify the impulse response function of the macroeconomic variables to the monetary policy shock $\epsilon_{1,t}$.

This approach is slightly different from the SVAR-IV approach (Mertens and Ravn, 2013; Stock and Watson, 2018) that is commonly used in the literature (Gertler and Karadi, 2015; Bauer and Swanson, 2022). The key difference is that the SVAR-IV approach requires invertibility of the VAR

$$\varepsilon_{1,t} \in \text{span}\left(\{w_\tau\}_{-\infty<\tau\leq t}\right).$$

Plagborg-Møller and Wolf (2022) and Miranda-Agrippino and Ricco (2023) show that non-invertibility can be an issue for these types of VARs. I verify robustness to using the VBS as external instrument in the appendix.

Estimation

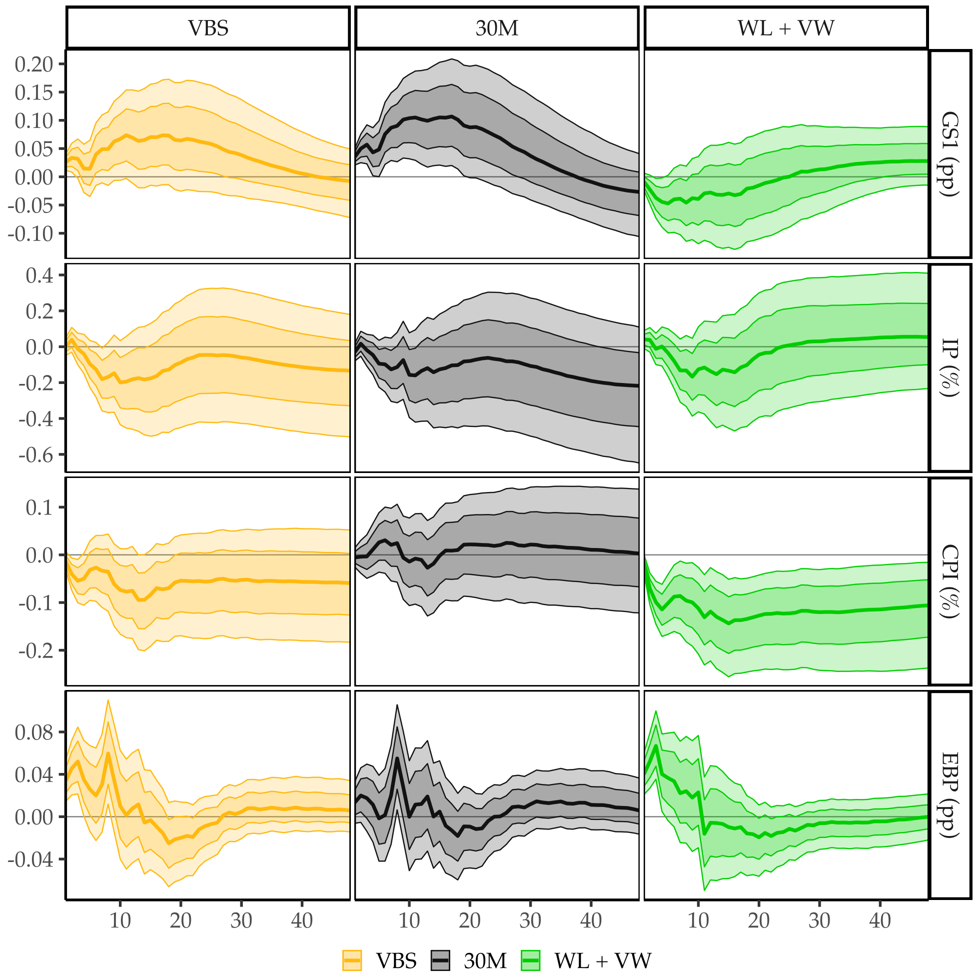
I estimate the VAR with flat priors estimated with the Ferroni and Canova (2021) toolbox. The advantage of using the toolbox is that it allows to repeat the analysis for different estimation methods in a straightforward manner. Therefore, I can consider estimation methods that lie at the opposite ends of the bias-variance trade-off (Li et al., 2022), such as local projections (Jordà, 2005) or Minnesota priors (Litterman, 1986) to investigate the robustness of the results. These results are reported in the appendix. The baseline flat prior VAR lies in between these two methods but can potentially incur bias if the lag length of the VAR is misspecified.

The sample runs from November 1988 to February 2020 and is at monthly frequency. The starting date is determined by the availability of the VBS, while the end date is chosen to avoid dealing with the large outliers during the Covid-19 pandemic. The system is estimated separately for the VBS and 30M-PC, as well as the unexplained portion of the VBS. The latter allows me to test if the VBS leads to different results than the 30M-PC due to the window length and volume-weighting components.

Results

The IRFs are reported in Figure 10. The figure shows that volume-based monetary policy surprises

Figure 10: The Impact of Monetary Policy Surprises on the Economy



The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-based monetary policy surprise, while other columns contain the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. 'WL + VW' refers to the unexplained variation in the volume-based monetary policy surprise. The VAR includes the monetary policy surprise, 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a Vectorautoregressive model with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021) with a flat prior. The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to February 2020 and is at monthly frequency.

exert a more substantial impact on the macroeconomy than their 30-minute window-based counterparts. Particularly striking is the difference in the inflation response. A contractionary 1SD monetary policy surprise decreases inflation by 0.1% after 12 months. In contrast, the 30M-PC leads to a negligible and insignificant response of inflation. In the appendix, I report the relative impulse response functions which detail that the VBS which raises the 1-year government bond yield by 25bp leads to a decline in inflation of 0.9% after 12 months.

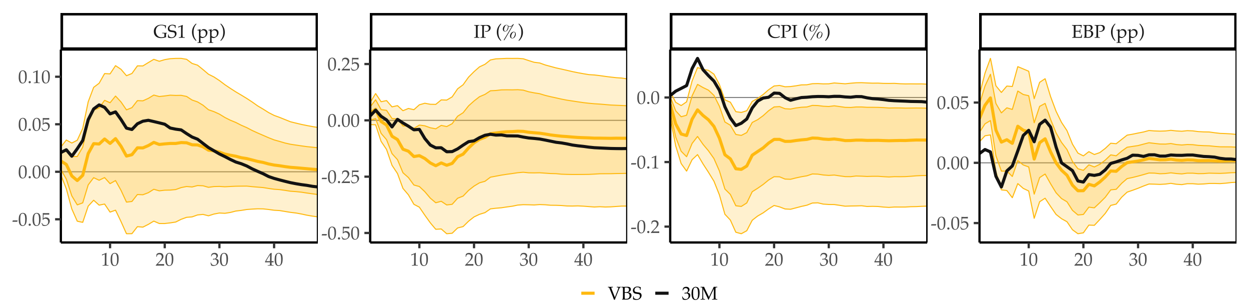
To more meaningfully test if there is a difference in the response of inflation, I use the unexplained portion of the VBS, consisting of the sum of the window length and volume-weighting components, as an internal instrument in the VAR. A 1SD increase in the volume-weighting and window lengths component lead to a large and significant decline in inflation of around 0.2% after 12 months, an effect that is highly significant at the 90% credible interval. Similarly, the responses of industrial production and excess bond premium move into the same direction between the VBS and 30M-PC, but the VBS leads to a larger response with the unexplained portion of the VBS driving the difference. This comes at a cost of a slightly smaller response of the monthly 1-year government bond yield which stands in contrast to the event study results in the previous section.

How does this compare to other estimates based on purely high-frequency measures of monetary policy surprises? In Gertler and Karadi (2015), the CPI response to a 1SD monetary policy surprise is small and only significant after around 3 years in a proxy VAR that runs from November 1979 to June 2012 and instrumenting with the three-month Fed Funds future from January 1991. Using local projections, which automatically reduces the sample to the time frame in which the instrument is available, Ramey (2016) finds a large discrepancy to the VAR results and no response of inflation to a monetary policy shock. In contrast, I show in the appendix that the VBS leads to a significant decline in inflation across local projections, Bayesian VARs with Minnesota priors, as well as in a proxy VAR using the surprises as external instruments.

In summary, the VBS helps to resolve the puzzle of the small inflation response to monetary policy shocks. The larger response is driven by the window length and volume-weighting components of the VBS, suggesting that these components capture important information about monetary policy shocks that the 30M-PC misses.

5.2 Decomposing the Monetary Policy Surprise

Figure 11: The Impact of Monetary Policy Surprises on the Economy - Path



The figure shows impulse response functions of several financial and macroeconomic variables to a 1 SD of the respective monetary policy surprise. The VAR includes the monetary policy surprise, 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained by a Flat Prior BVAR with a lag length of 12, estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are displayed for the Volume-based Monetary Policy Surprise and are based on 10000 draws from the posterior distribution. The sample is monthly and runs from November 1988 to February 2020.

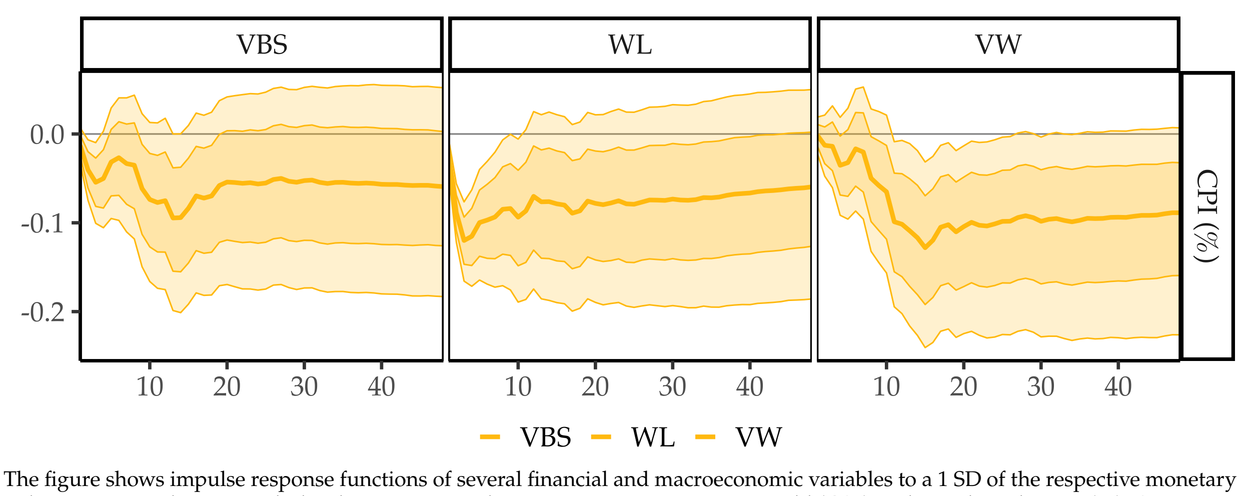
While the literature has focused a lot on the composite measures of monetary policy surprises, such as the 30M-PC, less attention has been paid if the macroeconomic effects are due the market surprise about the level shift in the fed funds rate (Target) or market's updating their expectations about the future path of monetary policy (Path). Therefore, I decompose the volume-based monetary policy surprise into its Target and Path components, by regressing the VBS on the Kuttner surprise/MP1 and taking the residuals as the Path component. The 30M-PC is decomposed by following the strategy in Gürkaynak et al. (2005), extracting two principal components from the inputs to the 30M-PC and rotating them such that the second component (Path) does not load on the Kuttner surprise/MP1.

The responses to the Path component of the VBS and 30M-PC are presented in Figure 11. A contractionary VBS Path component leads to a negative response of inflation and a positive response of the EBP, while 30M-PC Path as well as the VBS Path lead to a decline in output. Another difference is the response of the 1-year government bond yield, which is positive for the 30M-PC Path while the VBS Path has no impact on the 1-year government bond yield.

This is surprising as previously documented effects of the Path 30M-PC component on the economy are ambigious. A contractionary 30M-PC Path is shown to increase output forecasts of professional forecasters (Campbell et al., 2012; Nakamura and Steinsson, 2018) and leads to positive responses of output and inflation in VARs (Lakdawala, 2019; Swanson, 2023). This can be partly explained by FOMC forward guidance not giving information about policy inclinations but rather its view about the economic outlook (Lunsford, 2020). Indeed, during the zero lower bound period Path surprises are shown to lead to negative responses of output and inflation similar to the analysis above (Bundick and Smith, 2020).

To further enhance our understanding of the differences between the VBS and 30M-PC, I investigate the contribution of the individual components of the VBS, namely the window length and volume-weighting components to the CPI response. The results are presented in Figure 12. A 1SD increase in both components leads to a significant decline in inflation but at different horizons. The window length component leads to a near-term significant decline in inflation between horizons 0 to 10 and becomes insignificant thereafter. The volume-weighting component, on the other hand, leads to a significant and persistent decline in inflation that is significant at the 90% credible interval from horizon 10 to 24.

Figure 12: The Impact of Monetary Policy Surprises on Inflation - Window Length and Volume Weighting



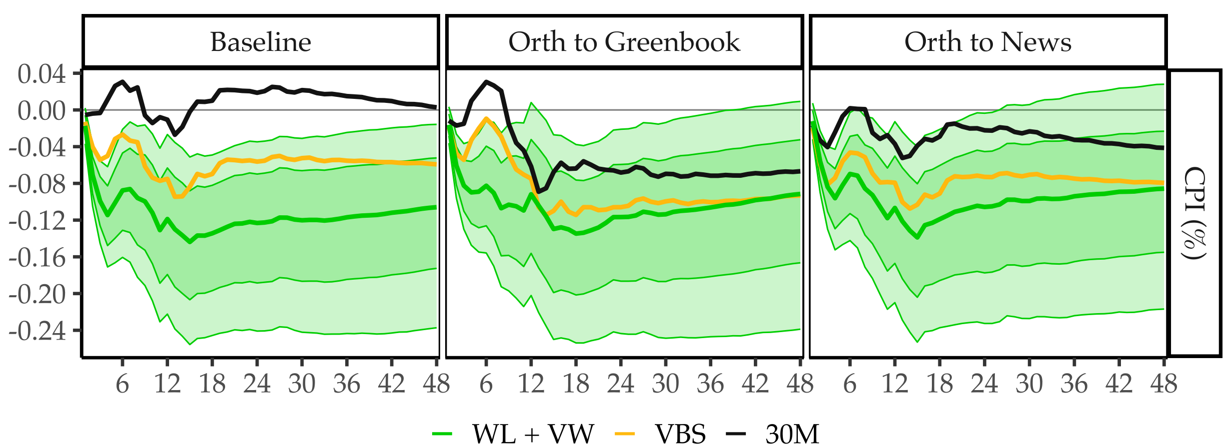
The figure shows impulse response functions of several financial and macroeconomic variables to a 1 SD of the respective monetary policy surprise. The VAR includes the monetary policy surprise, 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained by a Flat Prior BVAR with a lag length of 12, estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample is monthly and runs from November 1988 to February 2020.

5.3 Central Bank Information vs. Reaction to Economic News Effects

The above analysis implicitly assumes that any of the monetary policy surprises are surprises about interest rate expectations of market participants. Recently, evidence shows that monetary policy surprises are predictable by financial and macroeconomic news (Bauer and Swanson, 2022) and the Fed Information set (Miranda-Agrippino and Ricco, 2021). This predictability can be motivated by imperfect information between the market and the central bank about the central bank reaction function (Bauer and Swanson, 2023) or by the central bank information set (Miranda-Agrippino and Ricco, 2021).

To adjust for these effects, the proposed solution is to run announcement-frequency regressions, where the monetary policy surprise is the regression residual after adjusting for these predictors. To assess the impact of the economic news, I orthogonalize the VBS and 30M-PC to the predictors in Bauer and Swanson (2022) [2]. Similarly, I orthogonalize the VBS to the Fed Information set as in Miranda-Agrippino and Ricco (2021). Greenbook and Beige Book forecasts are only available with a 5-year lag which limits the sample to 1988/11 to 2019/06. Lastly, I adjust these surprises for autocorrelation. All regressions are reported in the appendix.

Figure 13: Reaction to News vs. Fed Information Effect



Each panel shows the impulse response function of a 1 SD Volume-based Monetary Policy Surprise (VBS), the 30-minute Principal Component (30M-PC) from Nakamura and Steinsson (2018) and the residual variation in the VBS which captures the window length and volume-weighting component (WL + VW). The first column shows the baseline response. The second panel adjusts all surprises to the predictors in the Greenbook (Miranda-Agrippino and Ricco, 2021). The third panel adjusts to economic news that predicts the surprises (Bauer and Swanson, 2023). The impulse response functions are obtained by a Flat Prior BVAR with a lag length of 12, estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first. The 68% and 90% credible intervals are displayed for the window-length and volume-weighting component based on 10000 draws from the posterior distribution. The sample is monthly and runs from November 1988 to February 2020.

The orthogonalized monetary policy surprises are then used to estimate the IRFs as before. The results are presented in Figure 13. Each column contains the IRFs of the unexplained portion of the VBS and 30M-PC, with its 90% and 68% credible intervals, and overlays the IRFs of the VBS and 30M-PC for comparison. The first column just repeats the IRFs to the VBS and 30M-PC from Figure 10 for comparison while the latter columns contain the IRFs of the orthogonalized VBS and 30M-PC. The orthogonalization has indeed an impact on the IRFs, particularly for the 30M-PC. In both cases, the response of inflation is now negative and

[2] Data from Bauer and Swanson (2022) is available at `https://www.frbsf.org/research-and-insights/data-and-indicators/monetary-policy-surprises/`

large. However, importantly it shifts the inflation response to the VBS by a similar magnitude and therefore the unexplained portion of the VBS stays highly significant and large. Therefore, the VBS approach is complementary to the orthogonalization approach in identifying the monetary policy shock and its impact on the economy.

6 Conclusion

This paper revisits the role of the assumption of fixed event windows and fixed loadings in the measurement of monetary policy surprise. In particular, this paper introduces annonuncement-specific window lengths and loadings for monetary policy surprises based on abnormal trading volume. The key finding is that the way information gets incorporated into prices and the FOMC communication both change substantially over time, which requires careful measurement of the underlying surprise to capture the true effects of monetary policy on financial markets and the economy. This can recover strong effects of monetary policy even at the zero-lower-bound and resolve puzzles about of a weak inflation response.

There are several directions for future research. First, the methodology devised in this paper can be applied in the broader event study context. It could help to relax the fixed-window assumption commonly employed in other paper that identify surprise in oil futures (Känzig, 2021) and government bond (futures) markets (Ray et al., 2024; Phillot, 2025). Secondly, this paper highlights the crucial of dispersed information, proxied by the volume response, after FOMC announcements. A general framework that allows for interactions of learning between the central bank and the market, as well as learning among participants with dispersed private information could help to address and unify the discussions around puzzles in the literature. This would enhance our understanding about the effectiveness of monetary policy, how markets forms price after central bank announcements and how to improve the central banks communication strategy.

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Appendix

A Theoretical Framework

This section outlines a simple framework that motivates why the choice of window length and loadings matters. It connects insights from the surprise measurement literature to the broader literature on trading around public announcements. The exposition is along the lines of Bauer and Swanson (2022), Miranda-Agrippino and Ricco (2021) & Jarociński and Karadi (2025) who focus on imperfect information between the FOMC and market participants. Here, the discussion focuses on the implications that arise with imperfect information across market participants. The framework does not constitute a formal model but rather a set of guiding principles for how choices in the construction of monetary policy surprises can be motivated by insights from the asset pricing under asymmetric information literature (see textbook treatment in Brunnermeier (2001); Vives (2010)). It then discusses the empirical behavior of short-term interest rate futures markets around FOMC announcements through the lens of this framework and motivates why announcement-specific window lengths and loadings are desirable.

The fundamental policy indicator is determined by the policy rule:

$$i_m = g(X_m; \theta_m) + \varepsilon_m$$

where θ_m represents policy parameters, X_m denotes economic state variables, and ε_m is the monetary policy shock - the unanticipated change in the policy indicator with variance σ_ε^2. The literature on monetary policy surprises focuses on imperfect information the policy rule (Bauer and Swanson, 2023) or the information the FOMC provides about the economic state (Miranda-Agrippino and Ricco, 2021; Jarociński and Karadi, 2020) with the prevalence of either being actively debated (Bauer and Swanson, 2023; Ricco and Savini, 2025; Jarociński and Karadi, 2025).

However, the arguments developed below hold when agents have perfect information about the policy rule and the economic state at each FOMC announcement which makes the discussion static across announcements and only focuses on the information processing across market participants at each announcement date. For the purpose of this discussion, the policy indicator i_m is latent and not directly observed by market participants. This nests the case of the federal funds target rate which market participants observe, but also the case of the path of future interest rates which is not directly observed.

In addition, in this paper I focus on the fact that it is desirable to include all information that the FOMC provides about the policy indicator i_m. FOMC communication are (exogenous) public signals about i_m and each announcement day contains only one true monetary policy shock. This includes the press release, the Summary of Economic Projections, and the Dot Plot when released jointly. An important caveat is that all these information releases could be treated as separate events and therefore should separately analyze press releases and press conferences(Altavilla et al., 2019; Acosta et al., 2025). The methods in this paper could be extended to separate these events.

The FOMC provides the market with information through its press releases, the Summary of Economic Projections including the dot plot, and press conferences. At each FOMC announcement m, market participants receive a public signal c_m about the policy indicator. The public signal follows:

$$c_m = i_m + \nu_m$$

where ν_m represents noise with variance σ_ν^2.

Therefore, consider the case where markets have perfect information about the policy rule and economic state but do not directly observe i_m. A Bayesian agent updates beliefs according to:

$$E[i_m|c_m] = \frac{1/\sigma_\varepsilon^2}{1/\sigma_\nu^2 + 1/\sigma_\varepsilon^2} g(X_m; \theta_m) + \frac{1/\sigma_\nu^2}{1/\sigma_\nu^2 + 1/\sigma_\varepsilon^2} c_m$$

When the FOMC provides a perfectly informative signal about i_m (i.e., $\sigma_\nu^2 \to 0$), then $E[i_m|c_m] \to i_m$. In this case, the only information that moves prices is the unanticipated policy change ε_m. This idea underlies the influential Kuttner (2001) surprise measure. The front-month federal funds future payoff is determined by the federal funds target rate at the end of the month. This captures the market's updated expectation under risk neutrality:

$$s_m^{Kuttner} = E[i_m|c_m] - E[i_m] = i_m - g(X_m; \theta_m) = \varepsilon_m$$

Any post-announcement price is valid to capture the surprise, as it is unlikely that there will be another FOMC meeting in the same month. Therefore, very short windows suffice to capture the surprise.

Path surprises present a more complex environment. There are two key differences compared to the target surprise. First, when the public signal c_m contains noise, the expectation $E[i_m|c_m]$ only partially adjusts to the monetary policy shock ε_m. Therefore, heterogeneity among market participants becomes relevant. Market participants may gain an advantage in their understanding of future policy paths through re-reading FOMC statements, proprietary term structure models, and other information sources. Second, at the end of the FOMC announcement day there is residual uncertainty in any asset that prices the path of interest rates as this will depend on future monetary policy decisions and changes in economic states.

In light of these differences the key question becomes: how quickly do prices become informative about the policy indicator i_m? Under standard efficient markets assumptions with homogeneous information processing, the no-trade theorem (Milgrom and Stokey, 1982) would imply no trading following public announcements, with prices being fully revealing immediately (Grossman, 1976). However, when prices are not fully revealing due to the presence of noise traders or behavioral biases, two insights from the asymmetric information literature become relevant.

In this case the above set-up can be analyzed through the lens of finite horizon dynamic noisy rational expectation models where agents receive and process private signals. There is an unknown fundamental (here the policy indicator i_m) that agents try to learn about through public signals (the FOMC announcement and price) and private signals (e.g., re-reading the FOMC statement, proprietary term structure models, and other information sources) and the finite horizon can be interpreted as the time until the market closes on the FOMC announcement day. Two insights from this literature are relevant.

First, they predict that volume and volatility react to new information. Even with risk-neutral market makers, there is active trading by informed agents (Vives, 1995). As market participants learn from their private signals and the public price signal, price informativeness increases over time, resolving differences in interpretation and incorporating dispersed information. More generally in these types of models (Vives, 2010), the speed of convergence depends on exogenously specified parameters such as the precision of the public signal, the degree of information asymmetry, the uncertainty about the fundamental, and the noise trading process. This can qualitatively explain the empirical patterns documented in Section 2 where volume and volatility spike at the announcement and then decay over time.

Second, if the assumption of the presence of a risk-neutral market maker is relaxed, prices can be semistrong non-efficient. With short-term risk-averse traders, i.i.d. noise trading and an informative (but not almost perfectly precise) public signal, Allen et al. (2006) show that prices underreact to a shock to fundamental as agents overweigh public information relative to their private information. Therefore, while the consensus opinion of market participants converges earlier to the true fundamental, prices only gradually incorporate this information over time. Depending on assumptions on the noise-trading process and the precision of the public signal multiple equilibria with different price informativeness can arise (Cespa and Vives, 2015) which lead to momentum or reversal patterns in prices. Similarly, given the fact that any asset pricing the path of interest rates will contain residual uncertainty about the fundamental at the end of the FOMC announcement day, these same patterns can arise with long-term traders (He and Wang, 1995; Cespa and Vives, 2012). This can explain why prices gradually incorporate the information over the FOMC announcement day and why this was an empirical exploitable pattern before the introduction of press conferences in 2011, as documented in Section B.2.

It is important to note that in reality the situation is likely more complex than the simple framework and corresponding models and literature discussed above. However, the empirical patterns are consistent with models where aggregating the information across all agents would immediately reveal the fundamental. Adequately modelling the complexity of processing the statement and learning about the reaction function of the FOMC and the economic state, as well as strategic interactions among agents, are likely to further complicate the price discovery process.

B High-Frequency Data

B.1 Summary Statistics

Table B.1 shows the summary statistics of the high-frequency data on Eurodollar Futures used in this paper.

Table B.1: Summary Statistics of 1-minute Eurodollar Futures Prices and Volume

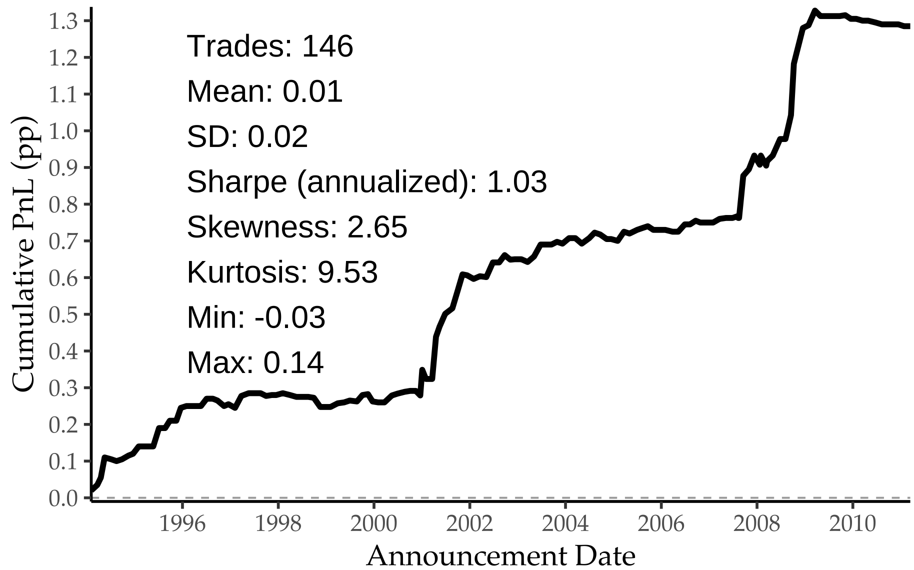
	1988/11-2003/11		2003/12-2022/12	
Statistic	Non-FOMC (N=2482)	FOMC (N=121)	Non-FOMC (N=3090)	FOMC (N=151)
Transactions			*Volume*	
Mean	1	2	1393	2363
SD	2	3	2947	4779
P01	0	0	0	0
P50	1	1	518	902
P99	11	16	12193	22851
Δ *P*			Δ *P*	
Mean	0.0014	0.0015	0.0009	0.0013
SD	0.0033	0.0039	0.0014	0.0026
P01	0	0	0	0
P50	0	0	0.0004	0.0008
P99	0.01	0.015	0.0058	0.01

This table shows the summary statistics of the 1-minute Eurodollar futures absolute price changes and volume. From 2003/12 to 2022/12 the sample is restricted between 09:00 to 17:00 ET and Volume is reported in contracts. During 1988/11 to 2003/11 the sample is restricted to 09:00 to 15:00 ET, due to the shorter trading hours in the Eurodollar Pit and the number of transactions is reported.

The data spans from November 1988 to December 2022 and contains 1-minute prices and volume for the first 12 quarterly Eurodollar futures contracts traded on the Chicago Mercantile Exchange (CME). The sample is split into two periods: 1988/11 to 2003/11 and 2003/12 to 2022/12. The first period corresponds to the time when Eurodollar futures were traded in the pit (Restricted Trading Hours/RTH), while the second period corresponds to the time when electronic trading became predominantly electronic (Extended Trading Hours/ETH). The trading hours are shorter in the pit, which is why the sample is restricted to 09:00 to 15:00 ET during that period. In contrast, the electronic trading occurs around the clock with an exception of a daily maintenance period from 17:00 to 18:00 ET.

The electronic trading dataset is also the one used for the estimations in Section 2 which is based on scheduled FOMC announcements between December 2003 and December 2022. Please note that some unscheduled FOMC announcement days occur earlier than 09:00 ET, which is why I use a slightly longer sample in the volume-based surprise creation. However, this would unnecessarily conflate the summary statistics with periods of relatively less trading activity and make them potentially less comparable.

Figure B.1: Cumulative PnL of Long-Short first Eurodollar Contract



The figure shows the cumulative PnL of a long-short strategy in the first Eurodollar contract that enters a long (short) position if there has been a rate increase (decrease) from 10 minutes before to 10 minutes after the FOMC announcement and closes the position once volume is not abnormal anymore. The sample includes all FOMC announcements from February 1994 to March 2011, before the introduction of press conferences.

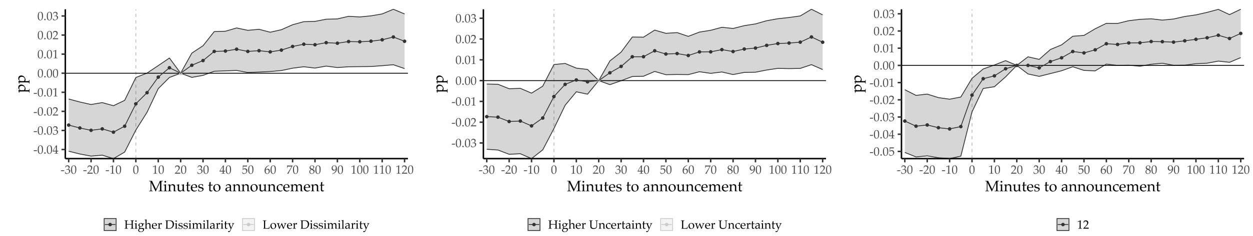
B.2 Trading Strategy

This section documents a simple trading strategy that shows that the price patterns documented in Section 2 were exploitable before the introduction of press conferences in 2011. The strategy entails going long (short) in the first quarter Eurodollar contract if there has been a rate increase (decrease) from 10 minutes before to 10 minutes after the FOMC announcement. The strategy therefore waits for the initial price jump induced by the FOMC press release, the public signal, and then bets on the subsequent drift in prices into the same direction. It closes the position once volume is not abnormal anymore (see next section). It generates a cumulative profit of up to 1.3 pp between 1994 and March 2011, before the introduction of press conferences. This amounts to an annualized Sharpe ratio of 1.03. The strategy has positive skewness of 2.65, with a few large positive returns and frequent negligible small or negative returns. It persists across 126 announcements over 17 years. A key caveat is that the strategy does not account for transaction costs, bid-ask spreads, and market impact. Fleming and Piazzesi (2005) document a similar pattern in government bond cash markets, but show that transaction costs prevent their strategy from being profitable.

B.3 Heterogeneity in Cumulative Price Response

I study how the price reaction varies with empirical proxies for public signal precision and uncertainty about the fundamental payoff of the future contract, which are exogenous parameters in many models in the finite horizon noisy rational expectations literature. Figure B.2 shows the difference in cumulative absolute price changes in Eurodollar futures between FOMC announcements with high and low values of these proxies, where high and low are defined relative to the median value. The first panel (a) shows the difference in cumulative absolute price changes between FOMC announcements with high and low text-based statement dissimilarity, with more detailed description in Appendix D. Statement dissimilarity

Figure B.2: Cumulative Absolute Price Changes - Heterogeneity



(a) Statement Dissimilarity **(b)** Monetary Policy Uncertainty **(c)** Dot Plot

Panels (a) and (b) show $\hat{\beta}_k$ and their 99% confidence intervals from

$$|P_{c,m,\tau} - P_{c,m,-10}| = \alpha_{c,m} + \alpha_{c,\tau} + \sum_{\substack{k=-30 \\ k\neq 20}}^{120} \beta_k \cdot \mathbb{1}\{\tau = k\} \cdot \mathbb{1}\{X_m > \text{median}(X)\} + \epsilon_{c,m,\tau}$$

where c denotes the contract, m indexes FOMC meetings, and τ denotes event time in minutes relative to the FOMC announcement. X_m is a characteristic of FOMC announcement m that captures heterogeneity in the information content of the announcement. The baseline period is $\tau = 20$. The interaction with event-time dummies provides within-group variation for identification despite the presence of contract × meeting and contract × time fixed effects. I consider two different characteristics: (a) text-based statement dissimilarity, which proxies for the amount of new information, and (b) Policy Rate Uncertainty (Bundick et al., 2024), which is a proxy for residual uncertainty as it measures option-implied volatility of Eurodollar futures on the day before the announcement. Panel (c) reports the difference in the cumulative absolute price change between the 12th and 1st Eurodollar contract when the Summary of Economic Projections (SEP) is released. The coefficients are estimated by OLS. The regression is estimated using only FOMC announcement days. Standard errors are clustered at the meeting level.

captures the amount of new information in the FOMC statement relative to the previous statement. The results show that announcements with high statement dissimilarity have a larger immediate jump in prices and a more pronounced drift afterwards, consistent with the idea that more new information requires more time for market participants to process but also that more information induces a jump in prices.

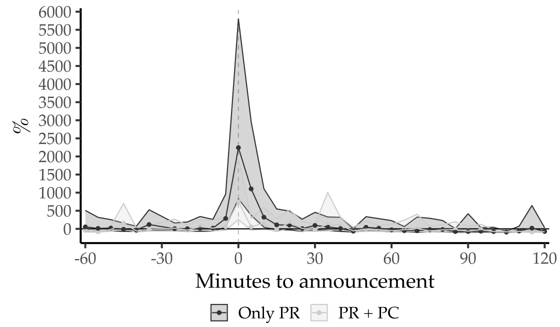
The second panel (b) shows the difference in cumulative absolute price changes between FOMC announcements with high and low levels Monetary Policy Uncertainty (MPU) (Bundick et al., 2024) on the day before the announcement. It captures the level of uncertainty and can also be seen as a proxy for the residual uncertainty of the payoff of the future. The results show that announcements with high MPU have a sustained and large drift in prices after the announcement, consistent with the idea that market participants put less weight on the price signals and their private information as it will be less valuable in predicting the payoff of the future.

The third panel (c) shows the difference in cumulative absolute price changes between the 12Q Eurodollar contract relative to the 1Q Eurodollar contracts on days the Summary of Economic Projections are released jointly with the FOMC statement. The SEP contains the FOMC's projections for GDP growth, unemployment, inflation and importantly, the federal funds rate over the next few years. The results show a sizable immediate jump in prices and a slight drift afterwards. This is consistent with the idea that the SEP send a precise public signal about the path of interest rates, which leads to an immediate jump in prices as the market incorporates the FOMC's view about the future path of interest rates.

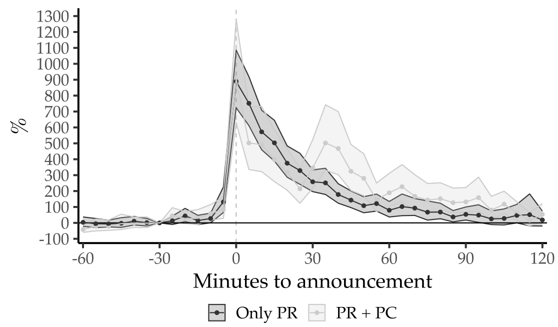
B.4 Poisson Regressions

The main text uses OLS regressions to estimate the patterns of trading volume, measured by the number of contracts traded, and absolute price changes around FOMC announcements. However, both dependent

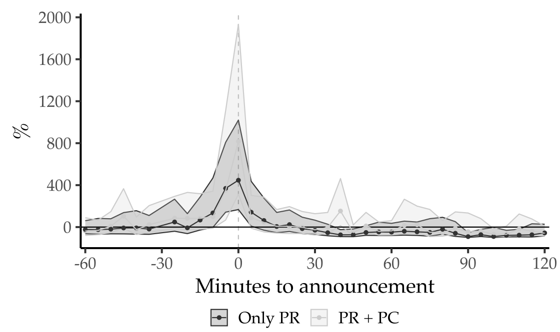
Figure B.3: Trading Volume and Absolute Price Changes Around FOMC Announcements - Poisson



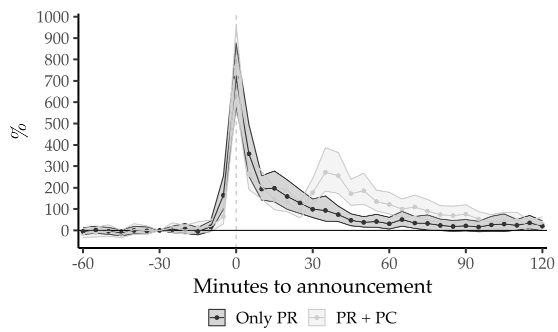
(a) Front-Month FFR Future Volume



(b) Eurodollar Futures Volume



(c) Front-Month FFR Future Price Volatility



(d) Q1-Q12 Eurodollar FuturesPrice Volatility

Panels (a) and (b) show the estimated $\hat{\beta_{t,m\in 0,1}}$ and their 99% confidence interval from

$$log(E[Volume_{m,d,t}|.]) = \alpha_{m,t^{5M}} + \alpha_d + \sum_{j=-60}^{j=120,j+=5} \beta_{j,m=1} \mathbb{1}_{t^{5M}=j} \mathbb{1}_{m=d}$$

where d denotes the day, t denotes time and m is a FOMC meeting indicator. Panel (c) and (d) show the estimated $\hat{\beta_{t,m\in 0,1}}$ and their 99% confidence interval from

$$log(E[|\Delta P_{c,m,d,t}|.]) = \alpha_{c,m,t^{5M}} + \alpha_{c,d} + \sum_{j=-60}^{j=120,j+=5} \beta_{j,m=1} \mathbb{1}_{t^{5M}=j} \mathbb{1}_{m=d}$$

where subscripts are similar to above and c denotes the contract. . denotes conditioning on the fixed effects and group indicators. The coefficients are estimated using Poisson regression. The sample runs from 2003-12-01 to 2022-12-31 and contains all scheduled FOMC announcements and the 21 prior trading days. The vertical line indicates the FOMC announcement at t=0. Standard errors are clustered at the day level.

variables are non-negative and right-skewed. I therefore report results from Poisson regressions in addition to the OLS regressions in the main text as they account for the count nature of the data and are consistent estimates (Cohn et al., 2022).

While the main text reports economically relevant magnitudes, as it focuses on DV01 for contracts and percentage points for the price changes in Eurodollar futures, the Poisson regression by construction reports the percentage change in the dependent variable. Therefore, this allows for a more direct comparison of the size in the relative change in volume and absolute price changes. Since the independent variables are a indicator variables, I transform the coefficients to percentage changes using $(\exp(\hat{\beta}) - 1) * 100$.

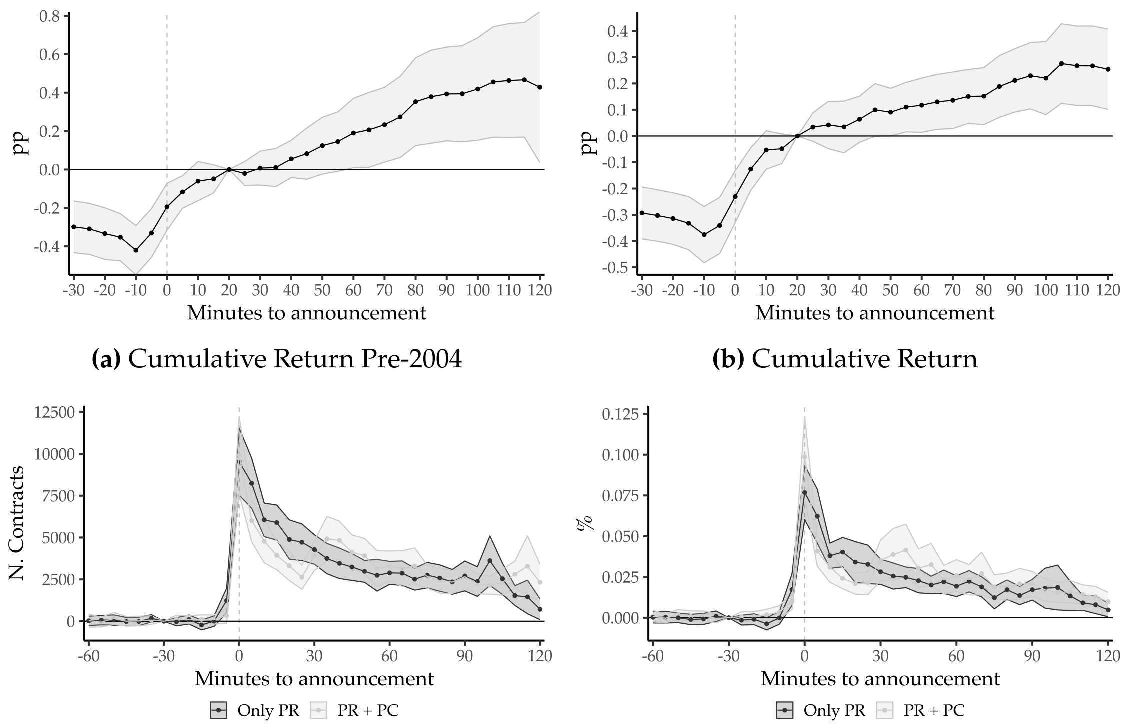
B.5 Equity Markets

Intuitively, the arguments of how agents process information from central bank announcements apply to equity markets as well. In this context, agents do not only need to process the information about the path of interest rates, but also how this in turn affects discount rates and future cash flows. (Zhu, 2023) documents in detail the behavior of the SPY ETF and the cross-section of equity markets around FOMC announcements and documents that volume spikes and then decays.

This section studies the post-announcement volume and return dynamics in the E-Mini S&P 500 futures contract (ES) traded on the CME. It confirms the findings in the Eurodollar market and shows that these patterns are even more pronounced in the E-Mini futures market.

Importantly, since E-Mini futures are traded electronically since their inception in 1997, it can provide some guidance if windows would have been longer even in the pre-2004 period. I find no qualitative difference in the cumulative return patterns, however, the absolute increase in cumulative return is sizablely larger in the pre-2004 period.

Figure B.4: Behavior of E-Mini Futures Around FOMC Announcements



(a) Cumulative Return Pre-2004

(b) Cumulative Return

(c) Volume

(d) Volatility

Panels (a) and (b) show the estimated $\hat{\beta_{t,m\in 0,1}}$ and their 99% confidence interval from

$$Volume_{m,d,t} = \exp(\alpha_{m,t^{5M}} + \alpha_d + \sum_{j=-60}^{j=120,j+=5} \beta_{j,m=1} \mathbb{1}_{t^{5M}=j} \mathbb{1}_{m=d} + \epsilon_{c,m,d,t})$$

where d denotes the day, t denotes time and m is a FOMC meeting indicator . Panel (c) and (d) show the estimated $\hat{\beta_{t,m\in 0,1}}$ and their 99% confidence interval from

$$|\Delta P_{c,m,d,t}| = \exp(\alpha_{c,m,t^{5M}} + \alpha_{c,d} + \sum_{j=-60}^{j=120,j+=5} \beta_{j,m=1} \mathbb{1}_{t^{5M}=j} \mathbb{1}_{m=d} + \epsilon_{c,m,d,t})$$

where subscripts are similar to above and c denotes the contract. The coefficients are estimated using Poisson regression. The sample (unless otherwise noted) runs from 2003-12-01 to 2018-12-31 and contains all scheduled FOMC announcement days without press conferences and the 21 prior trading days. The vertical line indicates the FOMC announcement at t=0. Standard errors are clustered at the day level.

C VBS: Additional Details

C.1 Step-by-Step Implemention

Let $V_{m,d,t} = \sum_{c=1}^{14} V_{m,d,t,c}$ denote aggregate trading volume across the fourteen Eurodollar contracts in minute t on day d, where m denotes the FOMC meeting. These eurodollar contracts are the first twelve quarterly contracts and two additional serial contracts that expire in the current quarter.

For each meeting m, the dataset includes the announcement day and 21 prior trading days.

Step 1: Bootstrap Normal Volume Distribution

For each 5-minute time bucket t^{5M}, I collect one-minute volumes:

$$\{V_{m,d-i,t}\}_{i=1}^{21,\ t\in t^{5M}}$$

Rather than resampling individual minutes independently, I perform a day-level cluster bootstrap (Rao and Wu, 1988) to preserve intraday correlation structure:

- Draw randomly 21 trading days d with replacement from the available 21 Pre-FOMC days
- For each drawn day d, include all 5 one-minute observations
- Compute the overall mean of pooled observations
- Repeat $B = 5{,}000$ times to form the bootstrap distribution
- Extract empirical 0.5% and 99.5% percentiles: $\widetilde{V}_{m,t^{5M}}^{\text{Normal},0.005}$ and $\widetilde{V}_{m,t^{5M}}^{\text{Normal},0.995}$

Step 2: Volume Smoothing

Calculate smoothed 1-minute average volume over the past 5 minutes:

$$V5M_{m,d,t} = \frac{1}{5}\sum_{i=0}^{4} V_{m,d,t-i}$$

This smoothing reduces noise while preserving the essential dynamics of volume evolution.

Step 3: Window Length Determination

Define the upper window bound as:

$$\overline{x_m} = \min\{x \mid x \geq 10 \text{ and } V5M_{m,d,t+x} < \widetilde{V}_{m,d,t}^{\text{Normal},0.995}\}$$

where x represents minutes after the FOMC press release.

Step 4: Press Conference Adjustment

For announcements with press conferences, I check for renewed abnormal volume during the conference period:

If there exists $t_0 \in [t_{PC}, t_{PC} + 75]$ such that for any 10-minute window $[t_0, t_0 + 10]$:

$$V5M_{m,d,t+x} > \widetilde{V}_{m,d,t}^{\text{Normal},0.995}$$

then restart the search for $\overline{x_m}$ from t_0.

Step 5: Volume-Based Loadings

The loading for each contract c is determined by its relative share of total volume:

$$\lambda_{m,c} = \frac{\sum_{h=t-10}^{t+\overline{x}_m} V_{m,d,h,c}}{\sum_{h=t-10}^{t+\overline{x}_m} \sum_{c=1}^{12} V_{m,d,h,c}}$$

.

The final Volume-Based Surprise (VBS) is:

$$VBS_m = \sum_{c=1}^{14} \lambda_{m,c} \left(P_{m,d,t+\overline{x}_m,c} - P_{m,d,t-10,c} \right).$$

C.2 Higher Statement Dissimilarity Predicts Longer Windows

An important aspect of Federal Reserve communication is the formal FOMC statement released jointly with the interest rate decision. This statement provides the rationale for policy decisions and has evolved substantially over time in both length and content. Media reports often focus intensively on changes in statement language, providing markets with immediate analysis of modifications that might signal shifts in policy stance or economic assessment [3]. Changes in statement content represent a key source of information for market participants.

To test whether our volume-based window lengths respond systematically to information content, I develop a text-based measure of statement dissimilarity. This measure is calculated as the cosine similarity $Similarity_m$ between the current FOMC statement and the previous statement, using term-frequency inverse document-frequency (TF-IDF) weights calculated on the current and all prior statements. A higher dissimilarity score, which is $1 - Similarity_m$, indicates a more substantial changes in statement content.

Figure C.1 displays both the time series of statement dissimilarity and its correlation with volume-based window lengths. The dissimilarity measure shows considerable variation over time, with particularly large values during periods of major policy shifts or economic stress. The figure also shows a clear positive correlation between statement dissimilarity and volume-based window lengths, suggesting that larger changes in statement content are associated with longer periods of information processing by market participants. A 0.1 increase in statement dissimilarity is associated with an 11.8 minute increase in the window length, indicating that more substantial changes in the statement lead to longer periods of elevated trading volume as markets digest the new information.

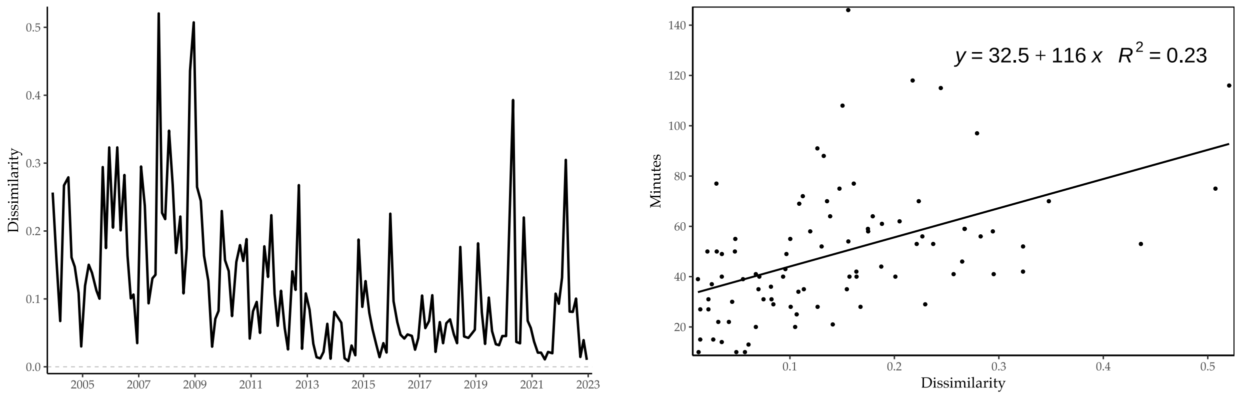
This relationship provides important validation of the volume-based approach. The results show that changes in the informational content of the statement, which can proxy for the amount of new information being conveyed, systematically predict that markets require more time to process this information.

C.3 Large Volume-Weight Component Aligns with Survey Forecast Errors

An important validation of our volume-weighting approach comes from examining how the weightings relate to direct measures of policy expectations. Three of the largest surprises in the volume-weighting

[3] For instance, the Wall Street Journal provides a "Fed Statement Tracker" which highlights changes in the statement. Its current version can be found here https://graphics.wsj.com/fed-statement-tracker-embed/

Figure C.1: Statement Dissimilarity Predicts Window Length



(a) Statement Dissimilarity **(b)** Window Length vs. Statement Dissimilarity

Statement dissimilarity is $1 - Similarity_m$, where $Similarity_m$ is the cosine similarity between the FOMC statement and the previous statement. A larger value signifies more changes in the statement. More details are provided in the appendix. The right panel shows a scatter plot of the volume-based window length $\overline{x}_m$ against statement dissimilarity. The sample period is 2003/11 to 2018/12, and excludes announcements with press conferences.

component occur in June 2013, September 2013, and March 2019 — all episodes involving significant forward guidance communications that shifted longer-term policy expectations.

One potential concern is that these changes might reflect spillovers from the Federal Reserve's asset purchase programs rather than genuine policy surprises about interest rate paths. To address this concern, I examine how changes in long-dated Eurodollar contracts align with survey-based measures of policy expectations, specifically comparing the Primary Dealer Survey conducted by the Federal Reserve Bank of New York with the Summary of Economic Projections (SEP) released by the FOMC.

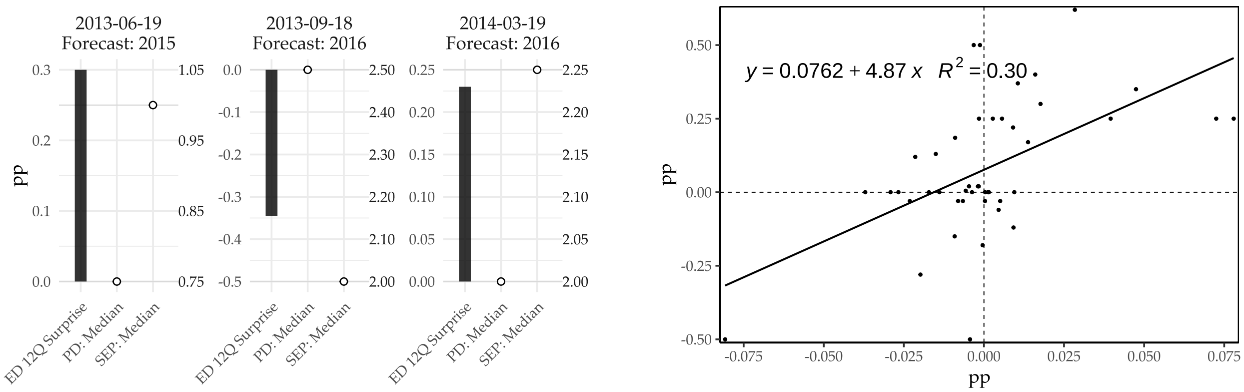
The Primary Dealer Survey asks primary dealers about their expectations for the federal funds rate at various horizons, while the SEP contains the median projections of FOMC members for the federal funds rate at specified future dates. Importantly, these surveys reflect expectations from different perspectives: market participants versus policymakers themselves.

Panel (a) of Figure C.2 shows the median projection for the year-end federal funds rate two and three years ahead from both surveys, alongside the change in the 12th Eurodollar contract, which incorporates similar horizons. In all three cases where large volume-weighting surprises occur, there is a substantial difference between the Primary Dealer Survey and the SEP of at least 25 basis points. Crucially, the 12th Eurodollar contract adjusts over our volume-based window to reflect this new information, moving at least 25 basis points in the same direction as the survey expectation error.

Panel (b) of Figure C.2 provides a scatter plot of the volume-weighting component against the farthest year out forecast error. The figure shows that this is a pattern that holds more generally: the volume-weighting component picks up surprises that originate from the Federal Reserve's dot plot. There is a highly statistically significant and positive relationship between the volume-weighting component and the survey forecast errors, with an R^2 of 0.3 .

These findings point to a previously unrecognized channel through which the Federal Reserve's communication affects markets: the alignment of market expectations with policymaker intentions. Market's

Figure C.2: Beliefs About Interest Rates: Primary Dealer Survey vs. Dot Plot



(a) Survey Forecast Differences

(b) Window Length Component vs. Survey Forecast Error

immediately price in the new information conveyed in the dot plots at the horizon where the market's and the FOMC's expectation diverge. The volume-based approach naturally captures this information by weighting contracts according to where the most active information processing occurs.

C.4 No confounding with Economic News

A concern is that the flexible windows based on abnormal volume might be adversely affected by the presence of other macroeconomic news releases. To address this concern, I download all macroeconomic news releases from Bloomberg Economic Calendar between October 1996 and December 2019 and keep the ones that occur on the FOMC announcement day and have a Bloomberg relevance score bigger than 0. In total, this encompasses the 125 most important news releases for the economy.

Most major macroeconomic news releases only occur prior to the FOMC press release. In particular, Table C.1 shows that before 174 FOMC announcements some economic news releases occur, of which on 37 days it is a major news release. A major news release is defined if it is in the top 5 most relevant news releases of the day as classified by Bloomberg and consists of the Non-Farm Payrolls, Jobless Claims, GDP, CPI and ISM Manufacturing Press Releases.

Table C.1: Economic News on the FOMC Announcement Day

		Prior (N=196)		After (N=33)	
		Mean	Std. Dev.	Mean	Std. Dev.
News (N.)		2.1	1.1	1.0	0.2
Clostest Release (Minutes)		271.3	94.9	168.1	98.1
		N	Pct.	N	Pct.
NFP | INJ | GDP | CPI | ISM	FALSE	147	75.0	33	100.0
	TRUE	49	25.0	0	0.0

The table describes summary statistics for all economic news releases of the Bloomberg Economic Calendar that occur on the FOMC announcement day between December 1996 and December 2022. It separates those into news release prior and after the FOMC press release. For each category, it calculates the average number of news releases and their distance to the press release. The last row verifies if important macroeconomic news releases occur prior or after the FOMC press release.

In contrast, there are no major news releases after the FOMC press release. However, there are still news releases that occur after 30 FOMC announcements. Table C.2 displays these news releases, their ranking among the 125 most important news releases and during which sample they overlap. 16 of these 24 news releases can be attributed to the Langer Consumer Comfort survey, which is released at 5pm New York time. In all of those cases, the volume-based window length ends before the news release occurs.

Table C.2: News Releases after the FOMC Press Release

Release	Meetings	Ranking	First Meeting	Last Meeting	Min Distance	News in Window
Consumer Credit	2	85	2002-05-07	2007-08-07	45	1
Langer Consumer Comfort	18	56	2005-03-22	2008-12-16	165	0
Monthly Budget Statement	4	37	2007-08-10	2013-10-30	90	2
U. of Mich. Sentiment	1	6	2007-08-17	2007-08-17	120	0
Pending Home Sales MoM	1	35	2008-10-08	2008-10-08	180	0
Wards Total Vehicle Sales	3	83	2010-11-03	2013-05-01	110	0
Net Long-term TIC Flows	5	41	2016-06-15	2022-06-15	120	0

The table displays news releases which occur after the FOMC press release between December 1996 and December 2022.

There is only three cases where the post-announcement news release overlaps with the volume-based window length. On August 7, 2007, the Consumer Credit report is released at 15:00 New York time. The volume-based window length for the fourth Eurodollar contract ends at 15:00 New York time. However, the Consumer Credit report ranks only at 76 out of 125 news releases. Therefore, I conclude it is unlikely that the volume-based window lengths are influenced by other news releases.

Secondly, the Treasury budget report is released jointly with the start of the press conference in September and December 2012. In both cases, the volume-based surprises picks up a spike in volume later then booth release dates, suggesting this is due to new information revealed by chairman Bernanke during the press conference.

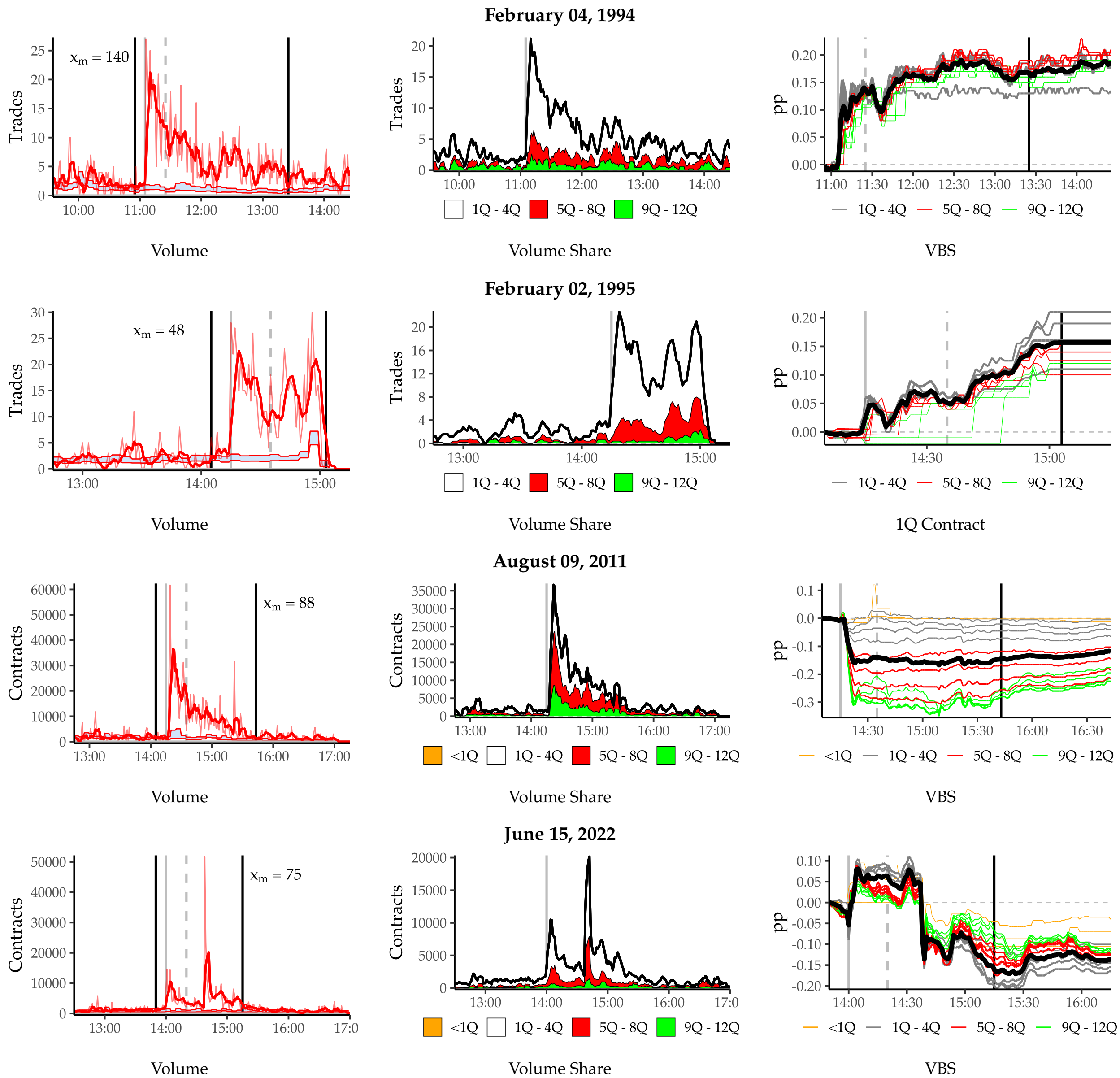
C.5 Narrative Evidence

Figure C.3 discusses announcements where the decomposition shows large differences between the VBS and PNS or the window lenghts are particularly pronounced. On February 2 1994, the FOMC released a statement, delivering a rationale for its rate hike for the first time in its history. This caught markets by surprise (The New York Times, 1994) and led to a continuous surge in transactions with implied rates of the first Eurodllar contract gradually pushing upwards. However, even though the window is substantially longer the resulting volume-based surprise is very close to the PNS.

On February 1, 1995, the Federal Reserve raised interest rates by 25 basis points which left market participants wondering when the peak of the tightening cycle would be reached (The New York Times, 1994) . The volume-based surprise is substantially larger than the PNS, mainly driven by the longer window length. The FOMC press release introduces a spike in transactions, that is sustained until the close of the Eurodollar pit at 15:00 ET. Implied interest rates of the first Eurodollar contract are quite volatile in the first 20 minutes after the FOMC announcement, but then continue to rise to their new level 10bp above the pre-announcement level.

On August 09, 2011, where the Federal Reserve announced that economic conditions are "likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013" (Board of Governors of the Federal Reserve System, 2011). At this explicit forward guidance announcement, trading volume is

Figure C.3: Examples: Eurodollar Market Response to FOMC Announcements



The figure shows the smoothed volume (in red) and implied interest rate (in black) for the fourth Eurodollar contract on 2005-03-22. The vertical line indicates the FOMC announcement at 13:15 Chicago/ 14:15 New York time. The dashed vertical grey line indicates the end of the 30-minute window. The blue-shaded area with red boundaries indicates the bootstrapped 99.5% and 0.005% confidence interval of the volume in a given minute over the past 31 trading days. The dashed red vertical line indicates where the trading volume falls into the blue-shaded area and trading volume has returned to normal.

concentrated at the longer horizons and the price of the eight-quarter Eurodollar future drops substantially. This leads to a large volume-based surprise, which is driven by volume-weighting component while the PNS is close to zero.

On June 15, 2022, where the Federal Reserve raised interest rates by 75 basis points, which was the largest increase since 1994. However, during the press conference, Federal Reserve Chair Jerome Powell indicated that the Federal Reserve raises of this size were not likely "be common" (Powell, 2022), which led to a large repricing in the Eurodollar market. The volume-based surprise, based on a upper window bound of 75 minutes, picks up this new piece of information, which is not captured by the 30-minute PNS.

In summary, the volume-based surprise captures how the Eurodollar market reacts to the FOMC announcements and its press release. For large unexpected announcements, this process can take a long time. On the other hand, for announcements with press conferences, there is new information to which the Eurodollar market reacts. The volume-weighting allows the surprise to flexibly adapt to the contracts in which trading, and therefore most information, is impounded into prices.

C.6 Loadings for Benchmark Surprises

This section reports the loadings of the input surprises on the first principal component for both the 30-minute and flexible window principal components in Table C.3.

The first principal component of the 30-minute price changes is the benchmark surprise measure used in the main text. It is created according to (Nakamura and Steinsson, 2018). The first principal component of the flexible window price changes is used in the construction of the window length component. It incorporates the flexible window lengths, described in the main text but estimates the weights by PCA rather than volume-weighting. The loadings of the principal components are similar in size.

Table C.3: Regression of Input Surprises on PCA Surprises

Sample	MP1	ED1	ED2	ED3	ED4
30M-PC	0.747	0.948	0.985	0.966	0.923
FlexWL-PC	0.687	0.947	0.984	0.966	0.912

This table reports the estimated loadings of input surprise measures (MP1 and Eurodollar futures, ED1–ED4) on the first principal component. Each entry shows the regression coefficient of the corresponding input on the PCA factor, with rows indicating the construction of the PCA surprise (30-minute window or flexible window).

D FOMC Statement Dissimilarity Calculation

This appendix provides a detailed description of the text-based dissimilarity measure used to quantify changes in FOMC statement content between consecutive meetings. The measure captures the degree of linguistic change and serves as a proxy for the informational content of Federal Reserve communications.

D.1 Text Preprocessing

Before calculating dissimilarity measures, each FOMC statement undergoes standardized preprocessing to remove non-substantive content and focus on policy-relevant language. The preprocessing consists of four main steps:

Step 1: Boilerplate Removal. I remove standard formatting elements and administrative text that appear consistently across statements but carry no policy information. This includes:

- Release headers and timestamps ("For immediate release", "For release at...")
- Contact information and administrative details
- Standard disclaimers and technical implementation notes
- Voting member listings with standard phrasing

Specifically, I apply the following regular expression patterns:

- `For immediate release`
- `For release at \d+:\d+ [APMapm]+`
- `Voting for the FOMC monetary policy action were:.*?˙`
- `Voting for this action:.*?˙`

Step 2: Text Normalization. I apply standard text cleaning procedures:

- Collapse multiple whitespace characters and line breaks into single spaces
- Remove special characters and formatting artifacts
- Convert text to lowercase for consistency

Step 3: Stopword Removal. I remove both standard English stopwords and FOMC-specific administrative terms that appear frequently but carry little substantive information:

- Standard stopwords: articles, prepositions, conjunctions
- FOMC-specific terms: "federal", "reserve", "fomc", "committee", "board", "governors", "chair", "chairman", "meeting", "statement", "press", "release", "action", "implementation", "note", "open", "market"

Step 4: Word Filtering. The final preprocessed text consists of content words that capture the substantive policy message of each statement.

D.2 TF-IDF Vectorization

Following text preprocessing, I transform each statement into a numerical representation using Term Frequency-Inverse Document Frequency (TF-IDF) weighting. This approach weights terms based on their importance within individual documents relative to their frequency across the entire corpus.

For a term t in statement s, the TF-IDF weight is calculated as:

$$\text{TF-IDF}(t,s) = \text{TF}(t,s) \times \text{IDF}(t)$$

where:

- $\text{TF}(t,s)$ is the term frequency of term t in statement s
- $\text{IDF}(t) = \log\left(\frac{N}{|\{s \in S : t \in s\}|}\right)$ is the inverse document frequency
- N is the total number of statements in the corpus
- $|\{s \in S : t \in s\}|$ is the number of statements containing term t

Vectorization Parameters:

- **Maximum features:** 1,000 terms (focuses on most informative vocabulary)
- **N-gram range:** (1,2) (captures both individual words and two-word phrases)
- **Sublinear TF scaling:** Applied to prevent bias toward longer documents

Time-Consistent Approach: To ensure temporal consistency and avoid look-ahead bias, I employ a recursive fitting procedure. For each statement s_t at time t, the TF-IDF vectorizer is fitted using only statements available up to time t: $\{s_1, s_2, ..., s_t\}$. This ensures that the vocabulary and IDF weights reflect only information available at the time of each statement's release.

D.3 Cosine Similarity Calculation

Once statements are transformed into TF-IDF vectors, I calculate pairwise similarity using cosine similarity, which measures the angular distance between two vectors regardless of their magnitude.

For statements s_t and s_{t-1} with TF-IDF vectors $\mathbf{v}_t$ and $\mathbf{v}_{t-1}$, cosine similarity is:

$$\text{Similarity}(s_t, s_{t-1}) = \frac{\mathbf{v}_t \cdot \mathbf{v}_{t-1}}{|\mathbf{v}_t||\mathbf{v}_{t-1}|} = \frac{\sum_{i=1}^{n} v_{t,i} \times v_{t-1,i}}{\sqrt{\sum_{i=1}^{n} v_{t,i}^2} \times \sqrt{\sum_{i=1}^{n} v_{t-1,i}^2}}$$

where n is the dimension of the TF-IDF vectors and $v_{t,i}$ represents the i-th component of vector $\mathbf{v}_t$.

Since the TF-IDF vectors are non-negative, cosine similarity ranges from 0 (completely dissimilar) to 1 (identical).

D.4 Dissimilarity Measure

Our primary measure of statement change is dissimilarity, defined as:

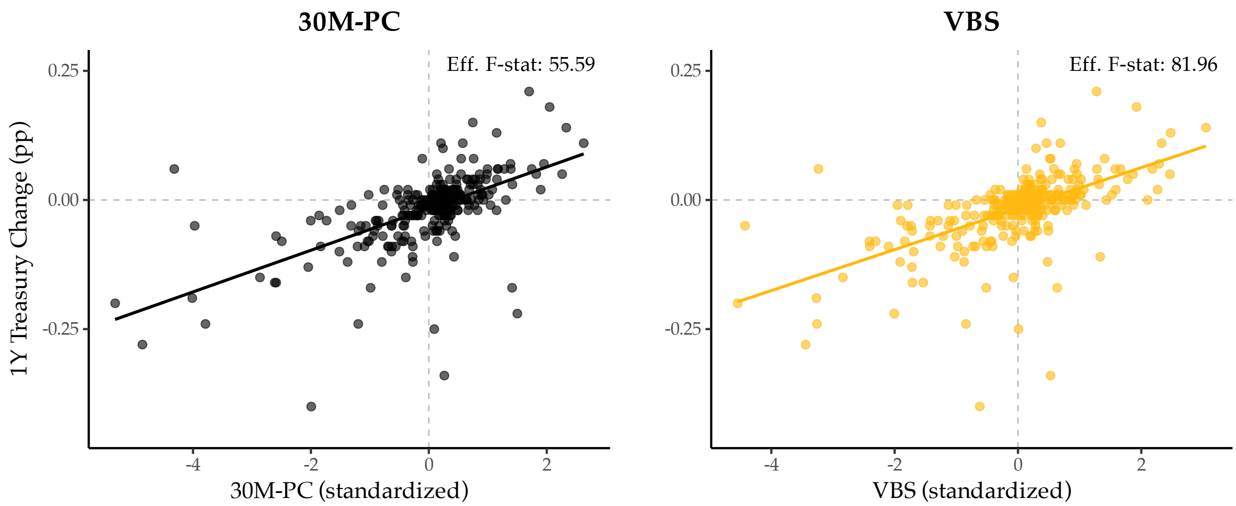
$$\text{Dissimilarity}(s_t, s_{t-1}) = 1 - \text{Similarity}(s_t, s_{t-1})$$

This transformation ensures that:

- Dissimilarity = 0 when statements are identical
- Dissimilarity increases as statements become more linguistically distinct
- The measure is bounded between 0 and 2 (with values near 2 being extremely rare in practice)

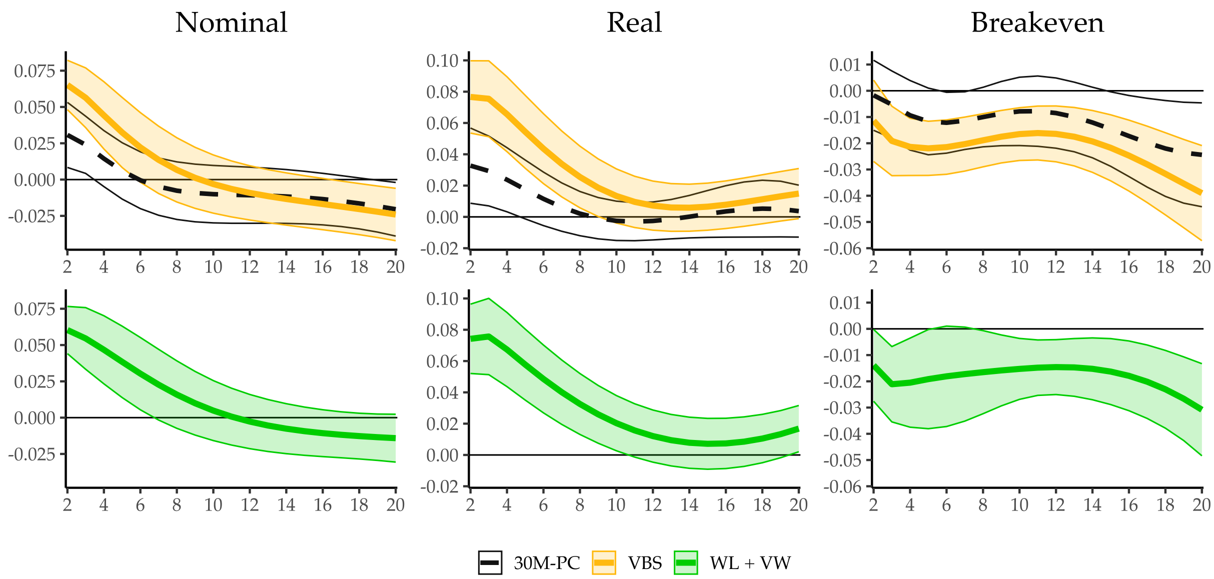
E Robustness & Extensions: Financial Markets

Figure E.1: Instrument Strength (Full Sample): 1-Year Yield on Monetary Policy Surprises



The figure shows the daily change in the 1-year Treasury yield (in pp) on the y-axis and the respective 1SD surprise measure on the x-axis. The sample includes all FOMC announcement from November 1988 to December 2022. The surprises are the first principal component of 30-minute price changes (30M-PC) (Nakamura and Steinsson, 2018) and the Volume-based Monetary Policy Surprise (VBS). The effective F-statistic (Olea and Pflueger, 2013) is reported for both specifications. The critical values for 10% bias are 23.1 and 37.4 for 5% bias respectively.

Figure E.2: Treasury Market - Forward Curves



The figure shows the 2-day change, from the day prior to the FOMC announcement to the day after, in the instantaneous forward rate of a Treasury security with maturity h (in pp) to the respective 1SD surprise measure

$$\Delta f_m^h = \alpha^h + \beta^h \cdot s_m + \epsilon_m^h.$$

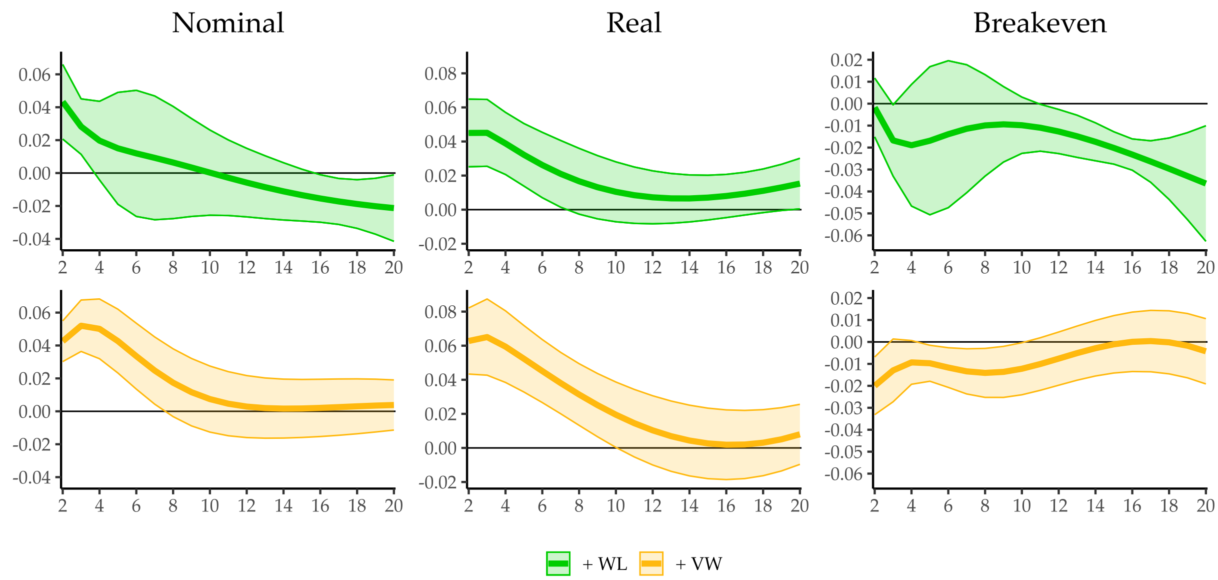
The surprises are the first principal component of 30-minute price changes (30M-PC) (Nakamura and Steinsson, 2018) and the Volume-based Monetary Policy Surprise (VBS). The sample includes all scheduled FOMC announcements from December 2003 to December 2022 excluding the Global Financial Crisis period (2008/07 to 2009/06) and March to June 2020. The underlying dataset for real and breakeven yields is Gürkaynak et al. (2010) and for nominal yields (Gürkaynak et al., 2007). The shaded areas represent 95% confidence intervals based on heteroskedasticity-robust (HC3) standard errors.

Table E.1: Treasury Market - Event Study Results (Including Crisis + Unscheduled)

	1988/11 - 2003/11 (n= 145)			2003/12 - 2022/12 (n= 159)		
	30M-PC	VBS	WL + VW	30M-PC	VBS	WL + VW
Dep Var: 1Y Treasury						
Estimate	0.049***	0.049***	0.008	0.028***	0.030***	0.014*
SE	(0.008)	(0.007)	(0.007)	(0.009)	(0.005)	(0.008)
R^2	0.402	0.390	0.004	0.257	0.287	0.055
Dep Var: 10Y Treasury						
Estimate	0.023***	0.028***	0.018**	0.020***	0.045***	0.045***
SE	(0.006)	(0.006)	(0.007)	(0.007)	(0.009)	(0.009)
R^2	0.119	0.182	0.071	0.056	0.323	0.315

This table reports the estimated coefficients of a regression selected Treasury market yields on the respective monetary policy surprise. All dependent variables stem from the Federal Reserve H.15 report and can be found here. Reported standard errors are heteroskedasticity-robust (HC3) and the stars indicate significance at the 10%, 5% and 1% level.

Figure E.3: Real and Breakeven Inflation Forward - Surprise Decomposition



The figure shows the 2-day change, from the day prior to the FOMC announcement to the day after, in the instantaneous forward rate of a Treasury security with maturity h (in pp) to the respective 1SD surprise measure

$$\Delta f_m^h = \alpha^h + \beta^h \cdot s_m + \epsilon_m^h.$$

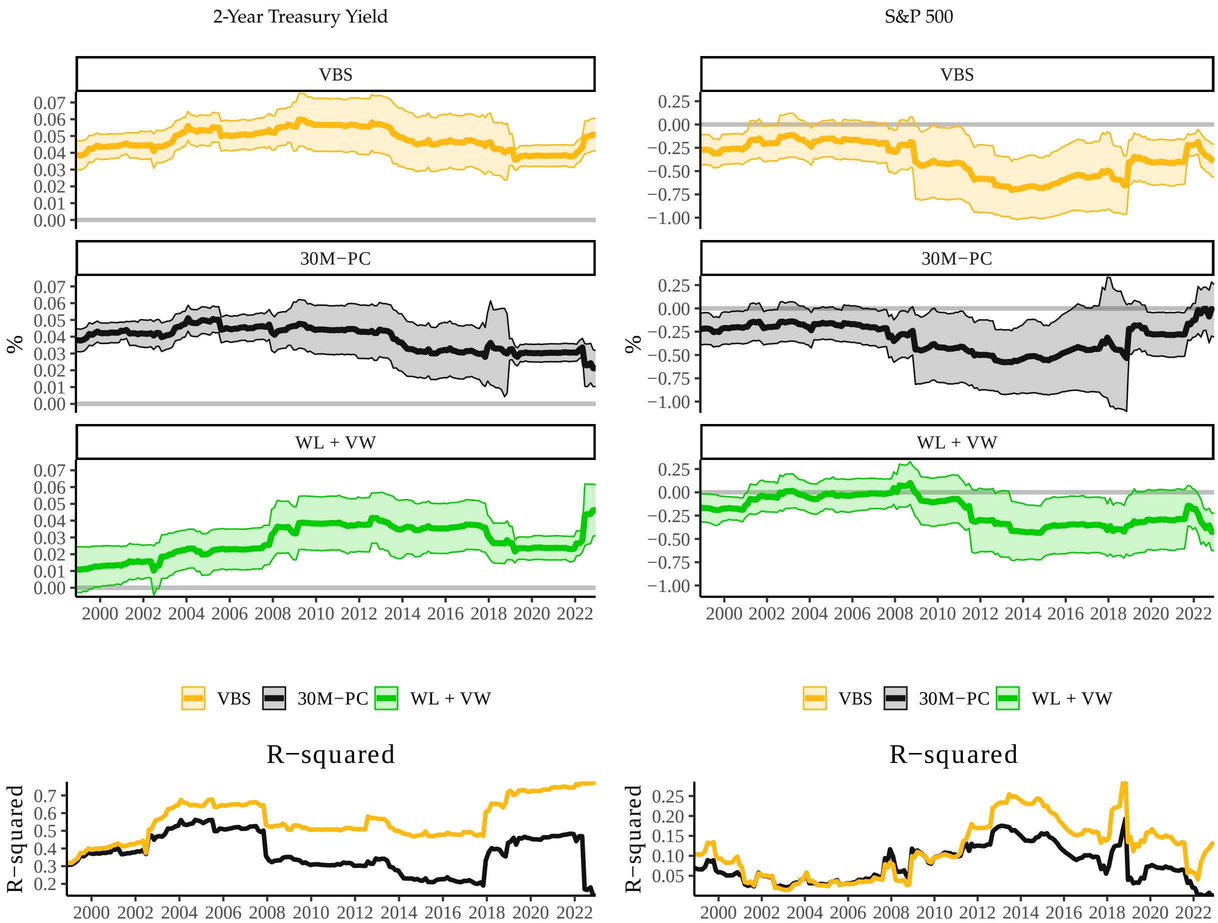
Here, s_m denotes the two components of the Volume-based Surprises: the window length component and the volume-weighting component. These components measure the difference in the VBS to the 30-minute principal component surprise (30M-PC) (Nakamura and Steinsson, 2018), due to announcement-specific window lengths and announcement-specific loadings respectively. The sample includes all scheduled FOMC announcements from December 2003 to December 2022 excluding the Global Financial Crisis period (2008/07 to 2009/06) and March to June 2020. The underlying dataset for real and breakeven yields is Gürkaynak et al. (2010) and for nominal yields (Gürkaynak et al., 2007). The shaded areas represent 95% confidence intervals based on heteroskedasticity-robust (HC3) standard errors.

Table E.2: Equity Market - Event Study Results (Including Crisis + Unscheduled)

	1988/11 - 2003/11 (n= 145)			2003/12 - 2022/12 (n= 159)		
	30M-PC	VBS	WL + VW	30M-PC	VBS	WL + VW
Dep Var: SP500 Future (Intraday)						
Estimate	-0.395***	-0.332***	0.055	-0.283***	-0.423***	-0.276**
SE	(0.082)	(0.080)	(0.078)	(0.067)	(0.083)	(0.117)
R^2	0.359	0.250	0.000	0.131	0.200	0.082
Dep Var: SP500 Total Return (Daily)						
Estimate	-0.481***	-0.432***	0.031	-0.176	-0.457***	-0.476***
SE	(0.117)	(0.113)	(0.102)	(0.218)	(0.145)	(0.116)
R^2	0.183	0.146	-0.006	0.011	0.113	0.123

This table reports the estimated coefficients of a regression of the stock market return on the respective monetary policy surprise on FOMC announcement days.
The S&P Future Return is calculated from the price of the E-Mini (Ticker: ES) contract after 1998 and the broad SP Future (Ticker: SP) in earlier sample periods. It is measured over the same window as the surprise. In the first column, the window is the 30-minute window, while in the second and third column, the window is the flexible window length. The daily CRSP value-weighted stock market return is measured on the day of the announcement. Reported standard errors are heteroskedasticity-robust (HC3) and the stars indicate significance at the 10%, 5% and 1% level.

Table E.3: Rolling Regression (10 Years) - Scheduled FOMC Announcements



This figure reports the estimated coefficients of a 10-year rolling regression of the daily return in the S&P 500 on a one standard deviation increase in the respective monetary policy surprise on scheduled FOMC announcement days. The first row shows the results of a regression using the Volume-based Monetary Policy Surprise (VBS) while the second row shows the results of a regression using the first principal component of 30-minute price changes (30M-PC) (Nakamura and Steinsson, 2018). The third row shows the residual of a regression of the VBS on the 30M-PC during the same rolling window and therefore captures the additional information in the VBS due to the flexible window length and volume-weighting 'WL+ VW'. The rolling window allows . The x-axis shows the end date of the rolling window. The S&P 500 return is downloaded from CRSP. Reported standard errors are heteroskedasticity-robust (HC3) and the shaded areas show the 90% confidence interval.

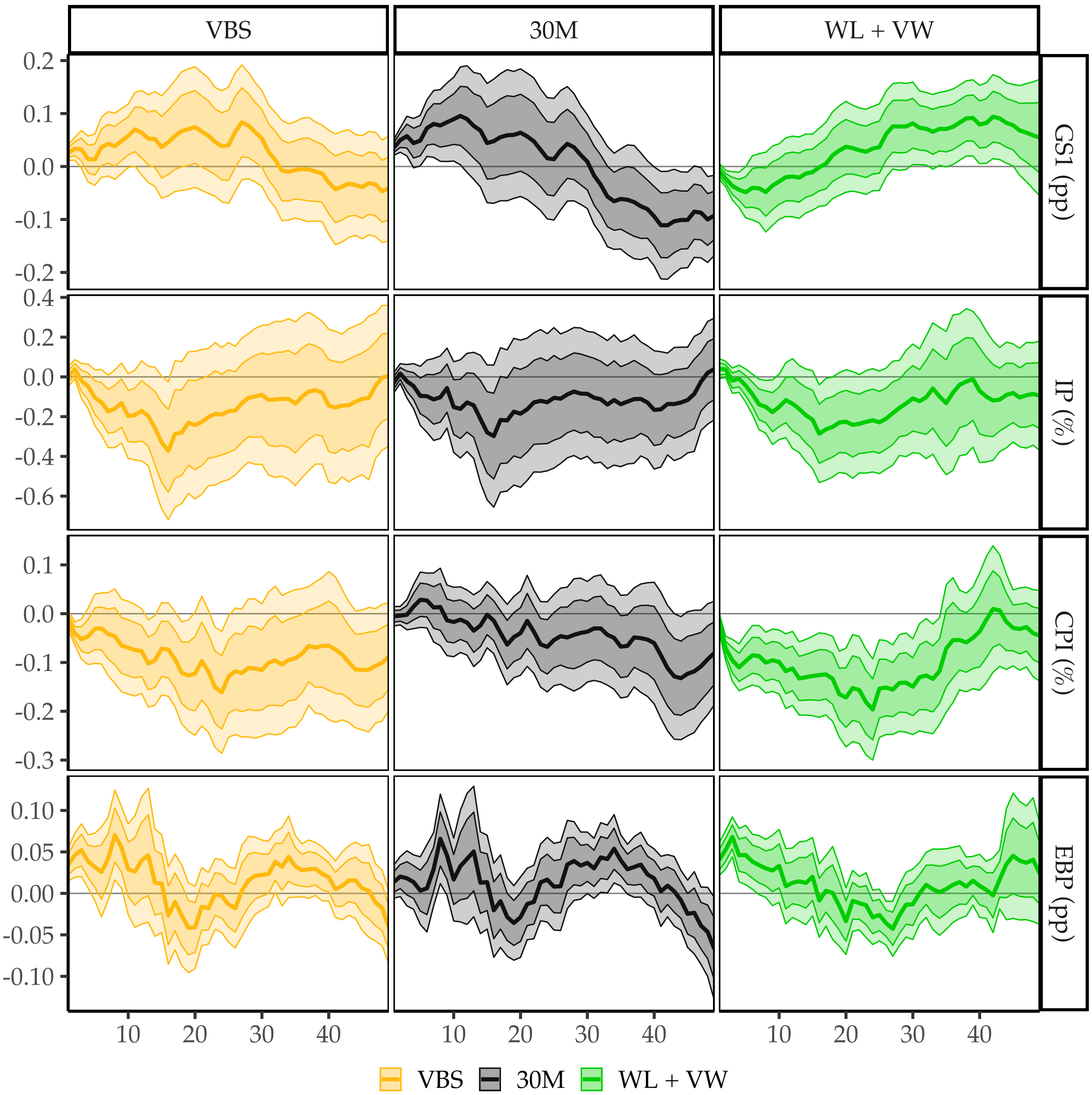
Table E.4: Uncertainty Measures - Event Study Results

	1990/01 - 2003/11 (n= 123)			2003/12 - 2022/12 (n= 142)		
	30M-PC	VBS	WL + VW	30M-PC	VBS	WL + VW
Dep Var: VIX						
Estimate	0.182	0.213*	0.125*	0.318	0.618**	0.547**
SE	(0.122)	(0.109)	(0.063)	(0.223)	(0.239)	(0.251)
R^2	0.023	0.036	0.007	0.014	0.074	0.057
Dep Var: KC Fed - Policy Rate Uncertainty						
Estimate	0.013***	0.014***	0.007**	0.005	0.012***	0.011**
SE	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
R^2	0.148	0.185	0.035	0.021	0.173	0.169

This table reports the estimated coefficients of a regression selected Treasury market yields on the respective monetary policy surprise on scheduled FOMC announcement days. I exclude all announcements during the Global Financial Crisis period (2008/07 to 2009/06) and March to June 2020. The VIX index is downloaded from FRED and can be found here. The Policy Rate Uncertainty (PRU) is calculated by the Kansas City Fed (Bundick et al., 2024). Reported standard errors are heteroskedasticity-robust (HC3) and the stars indicate significance at the 10%, 5% and 1% level.

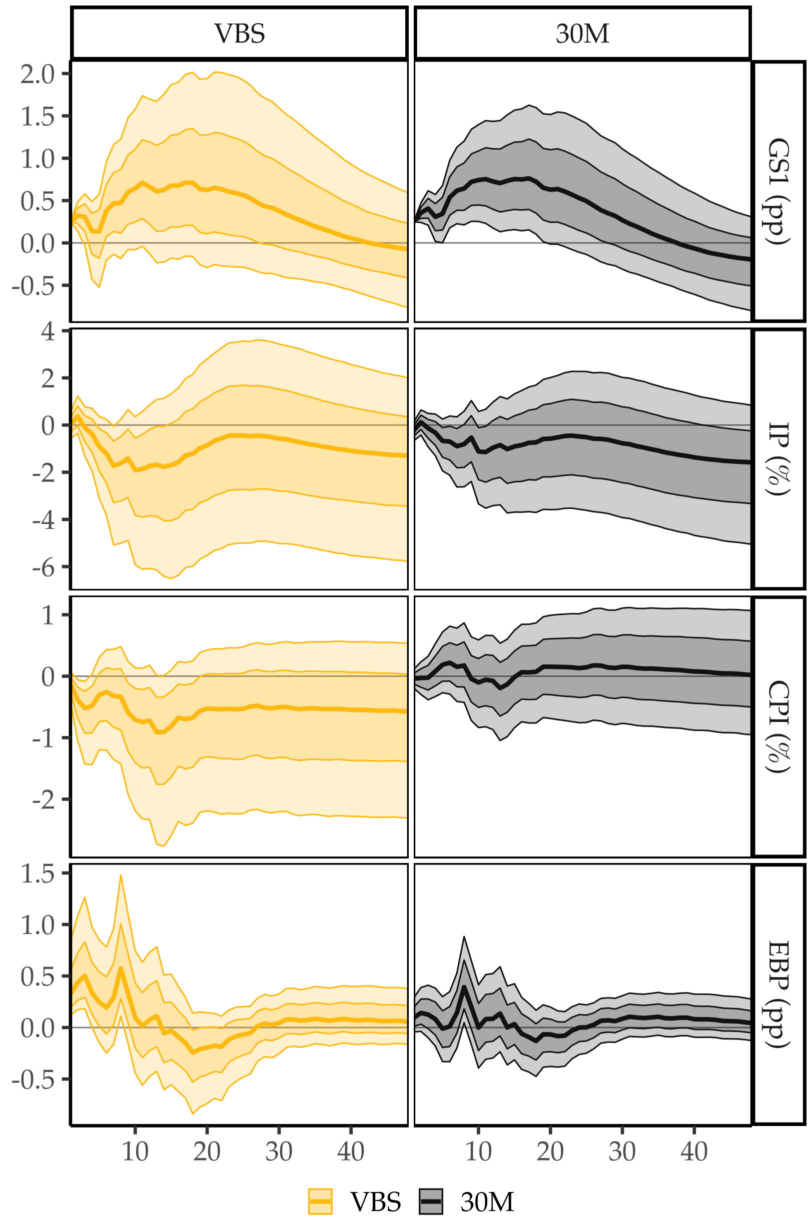
F Robustness: Macroeconomic Effects

Figure F.1: Revisiting Figure 10 - Local Projections



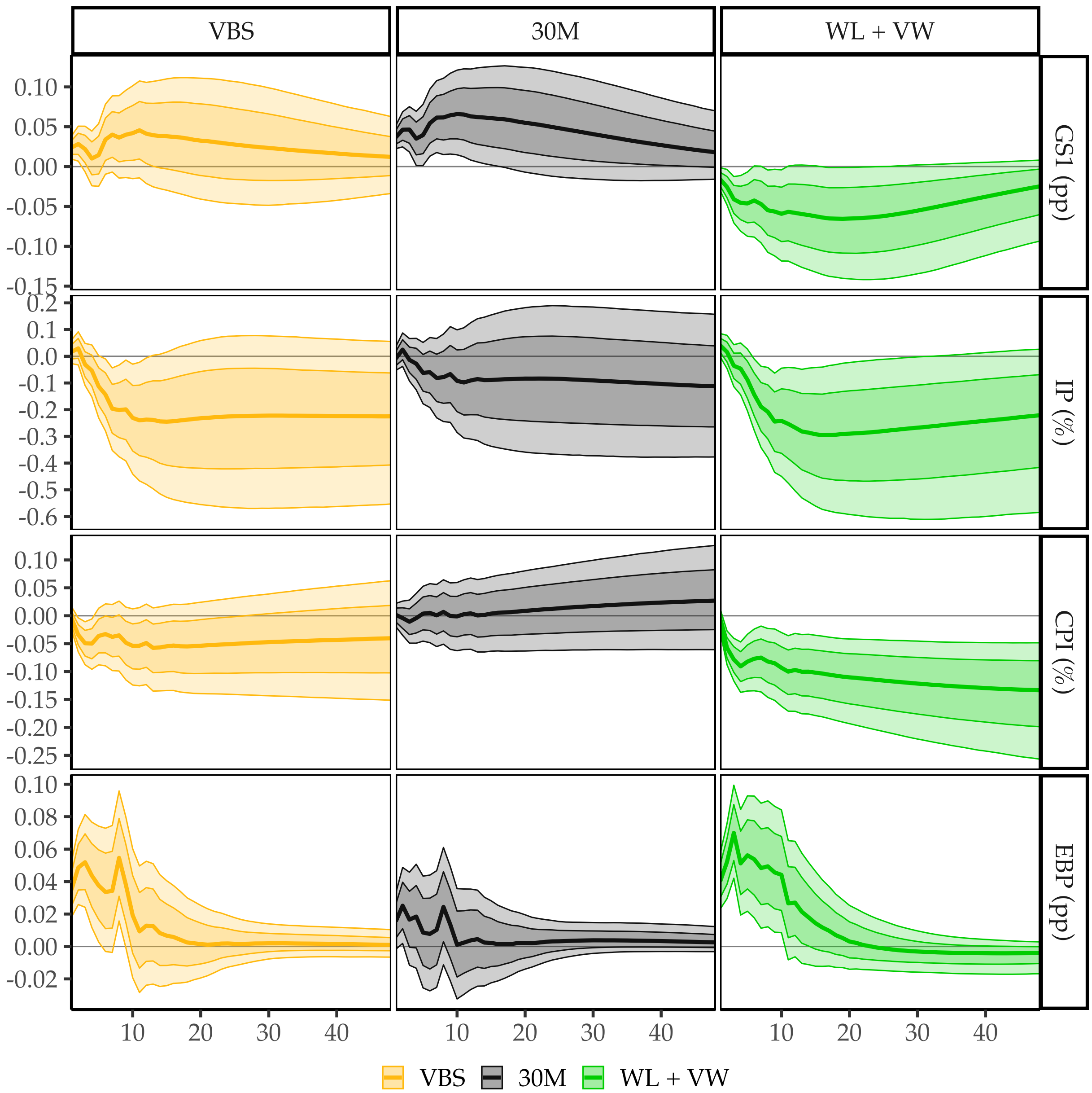
The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-weighted monetary policy surprise, while other column refer to the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. The set of controls includes 12 lags of the monetary policy surprise, 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a Local Projection with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to February 2020 and is at monthly frequency.

Figure F.2: Revisiting Figure 10 - Internal Instrument Rescaled



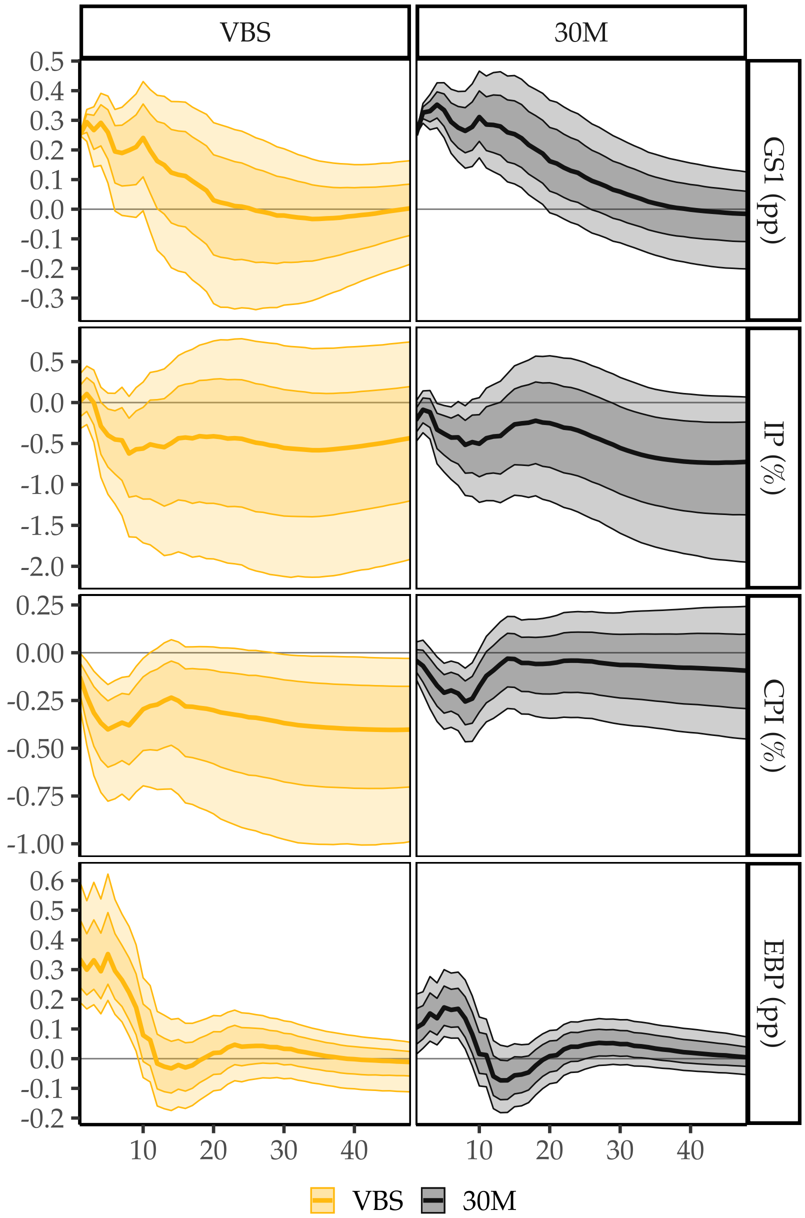
The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-based monetary policy surprise, while other columns contain the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. 'WL + VW' refers to the unexplained variation in the volume-based monetary policy surprise. The VAR includes the 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a flat prior Bayesian VAR with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to February 2020 and is at monthly frequency.

Figure F.3: Revisiting Figure 10 - Minnesota Prior



The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-based monetary policy surprise, while other columns contain the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. 'WL + VW' refers to the unexplained variation in the volume-based monetary policy surprise. The VAR includes the 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a Bayesian VAR with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021) with a Minnesota prior. The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to February 2020 and is at monthly frequency.

Figure F.4: Revisiting Figure 10 - Proxy SVAR



The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-based monetary policy surprise, while other columns contain the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. 'WL + VW' refers to the unexplained variation in the volume-based monetary policy surprise. The VAR includes the 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a Local Projection with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is used as an external instrument in a proxy SVAR for the 1-year Treasury yield (GS1). The robust F-statistics are 9.7 (30M) and 5.1 (VBS), which indicates that both instruments are weak for the residuals of the 1-year Treasury yield. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to February 2020 and is at monthly frequency.

Table F.1: Ortho News and Ortho Info Regression Results

Ortho News

	VBS	30M	VBS Residuals
NFP Surprise	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
NFP 12M	0.005**	0.004***	0.000
	(0.002)	(0.001)	(0.001)
BCom 3M	0.099	0.122**	-0.016
	(0.083)	(0.053)	(0.024)
TR Skew	0.033**	0.028**	0.002
	(0.016)	(0.012)	(0.006)
SP500 3M	0.124	0.081	0.022
	(0.083)	(0.057)	(0.029)
Slope 3M	-0.011	-0.016*	0.003
	(0.011)	(0.008)	(0.004)
R2 Adj.	0.072	0.116	-0.007
Num.Obs.	304	304	304

* p < 0.1, ** p < 0.05, *** p < 0.01

Ortho Info

	VBS	30M	VBS Residuals
(Intercept)	-0.044	-0.025	-0.003
	(0.039)	(0.031)	(0.012)
grgdpb1	0.003	0.001	0.001
	(0.004)	(0.003)	(0.001)
grgdpf0	0.017**	0.013**	0.001
	(0.007)	(0.006)	(0.002)
grgdpf1	-0.002	0.003	-0.003
	(0.011)	(0.010)	(0.003)
grgdpf2	-0.021	-0.016	-0.002
	(0.013)	(0.011)	(0.003)
grgdpf3	0.012	0.003	0.005
	(0.014)	(0.012)	(0.003)
grgdpb1rev	-0.001	-0.001	0.000
	(0.004)	(0.003)	(0.001)
grgdpf0rev	-0.002	0.001	-0.001
	(0.006)	(0.005)	(0.002)
grgdpf1rev	0.018**	0.010	0.004
	(0.008)	(0.007)	(0.003)
grgdpf2rev	0.030***	0.020**	0.005
	(0.009)	(0.008)	(0.003)
gpgdpb1	0.015*	0.010	0.003
	(0.009)	(0.007)	(0.002)
gpgdpf0	0.001	0.003	-0.001
	(0.010)	(0.007)	(0.003)
gpgdpf1	0.000	-0.002	0.002
	(0.013)	(0.011)	(0.003)
gpgdpf2	0.010	0.000	0.005
	(0.017)	(0.012)	(0.006)
gpgdpf3	-0.016	-0.007	-0.005
	(0.019)	(0.012)	(0.007)
gpgdpb1rev	-0.003	-0.007	0.002
	(0.007)	(0.005)	(0.002)
gpgdpf0rev	0.014	0.007	0.004
	(0.010)	(0.008)	(0.003)
gpgdpf1rev	0.002	0.002	0.000
	(0.013)	(0.009)	(0.004)
gpgdpf2rev	-0.002	0.006	-0.004
	(0.016)	(0.012)	(0.005)
unempb1	-0.042	-0.013	-0.016
	(0.055)	(0.039)	(0.017)
unempf0	0.143	0.052	0.050
	(0.105)	(0.076)	(0.039)
unempf1	-0.052	0.024	-0.043
	(0.129)	(0.106)	(0.039)
unempf2	-0.017	-0.048	0.019
	(0.135)	(0.104)	(0.042)
unempf3	-0.033	-0.012	-0.011
	(0.085)	(0.067)	(0.025)
unempb1rev	0.037	0.005	0.018
	(0.030)	(0.020)	(0.012)
unempf0rev	-0.120*	-0.021	-0.056***
	(0.068)	(0.054)	(0.021)
unempf1rev	-0.065	-0.099	0.022
	(0.096)	(0.073)	(0.031)
unempf2rev	0.177**	0.144***	0.014
	(0.076)	(0.054)	(0.028)
R2 Adj.	0.138	0.121	0.052
Num.Obs.	274	274	274

* p < 0.1, ** p < 0.05, *** p < 0.01

The left table reports the regression results of the respective surprise to the predictors in Bauer and Swanson (2022). The right table reports the regression results of the respective surprise to the predictors in Miranda-Agrippino and Ricco (2021)

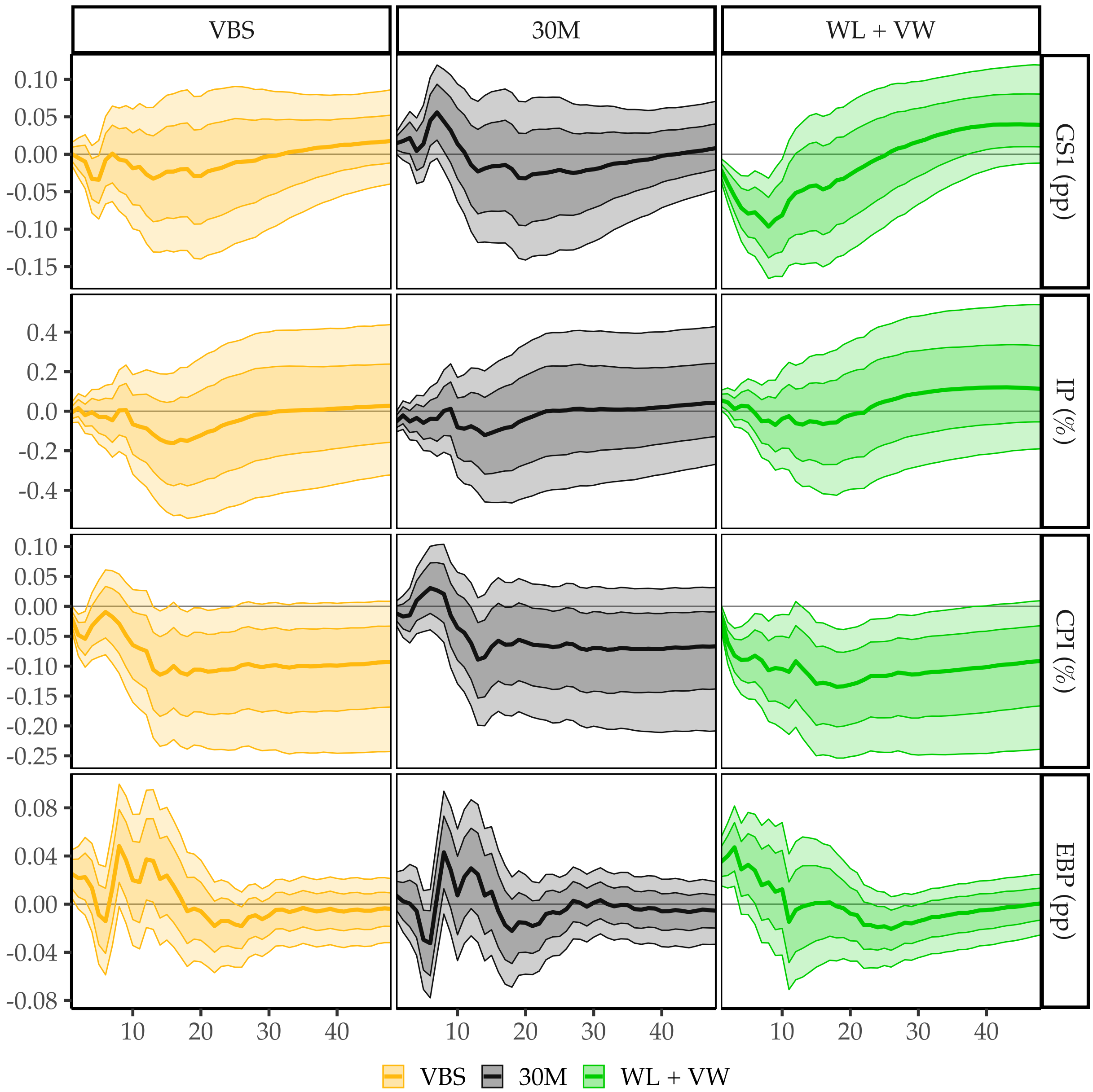
Table F.2: Ortho News and Ortho Info Autocorrelation Adjustment

	VBS	30M	VBS Residuals	VBS Orth	30M Orth	VBS Residuals Orth	VBS Non-Info	30M Non-Info	VBS Residuals Non-Info
Lag 1	0.134*	0.195**	0.150	0.109	0.061	0.150	-0.045	-0.043	0.118
	(0.079)	(0.091)	(0.117)	(0.109)	(0.091)	(0.113)	(0.097)	(0.097)	(0.108)
Lag 2	0.014	-0.013	0.074	-0.022	-0.074	0.076	-0.103	-0.157*	0.055
	(0.085)	(0.093)	(0.102)	(0.083)	(0.093)	(0.099)	(0.089)	(0.092)	(0.106)
Lag 3	-0.077	0.040	-0.232**	-0.153**	-0.003	-0.215**	-0.139*	-0.031	-0.166*
	(0.071)	(0.081)	(0.110)	(0.076)	(0.078)	(0.108)	(0.077)	(0.086)	(0.090)
Lag 4	0.145**	0.199***	-0.067	0.095	0.171**	-0.065	0.126*	0.111	0.004
	(0.061)	(0.073)	(0.089)	(0.067)	(0.070)	(0.086)	(0.072)	(0.080)	(0.087)
Lag 5	0.095	0.010	0.132*	0.098	0.045	0.130*	0.095	0.011	0.185**
	(0.074)	(0.077)	(0.079)	(0.081)	(0.081)	(0.079)	(0.084)	(0.082)	(0.083)
Lag 6	0.028	0.013	0.013	0.060	0.018	0.023	0.074	-0.016	0.037
	(0.070)	(0.071)	(0.081)	(0.092)	(0.080)	(0.079)	(0.095)	(0.077)	(0.078)
Lag 7	-0.022	-0.071	-0.049	0.014	-0.080	-0.059	0.076	-0.049	0.017
	(0.063)	(0.061)	(0.092)	(0.078)	(0.069)	(0.089)	(0.089)	(0.060)	(0.085)
Lag 8	-0.017	0.058	0.106	0.037	0.028	0.089	0.052	0.063	0.145
	(0.065)	(0.064)	(0.104)	(0.066)	(0.066)	(0.102)	(0.082)	(0.059)	(0.093)
Lag 9	0.024	0.013	0.057	0.028	-0.027	0.051	0.100	0.051	0.033
	(0.062)	(0.073)	(0.088)	(0.061)	(0.058)	(0.089)	(0.064)	(0.062)	(0.080)
Lag 10	-0.020	0.017	-0.083	-0.041	0.014	-0.084	-0.008	0.037	-0.090
	(0.062)	(0.071)	(0.075)	(0.065)	(0.070)	(0.073)	(0.061)	(0.070)	(0.071)
Lag 11	0.060	0.081	0.030	0.067	0.126**	0.033	0.042	0.073	-0.019
	(0.060)	(0.059)	(0.075)	(0.076)	(0.062)	(0.073)	(0.072)	(0.059)	(0.078)
Lag 12	-0.064	-0.086	-0.023	-0.051	-0.021	-0.029	-0.043	-0.067	0.003
	(0.055)	(0.055)	(0.057)	(0.076)	(0.070)	(0.057)	(0.067)	(0.058)	(0.068)
R2 Adj.	0.028	0.066	0.061	0.028	0.022	0.052	0.032	0.021	0.051
Num.Obs.	292	292	292	292	292	292	262	262	262

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

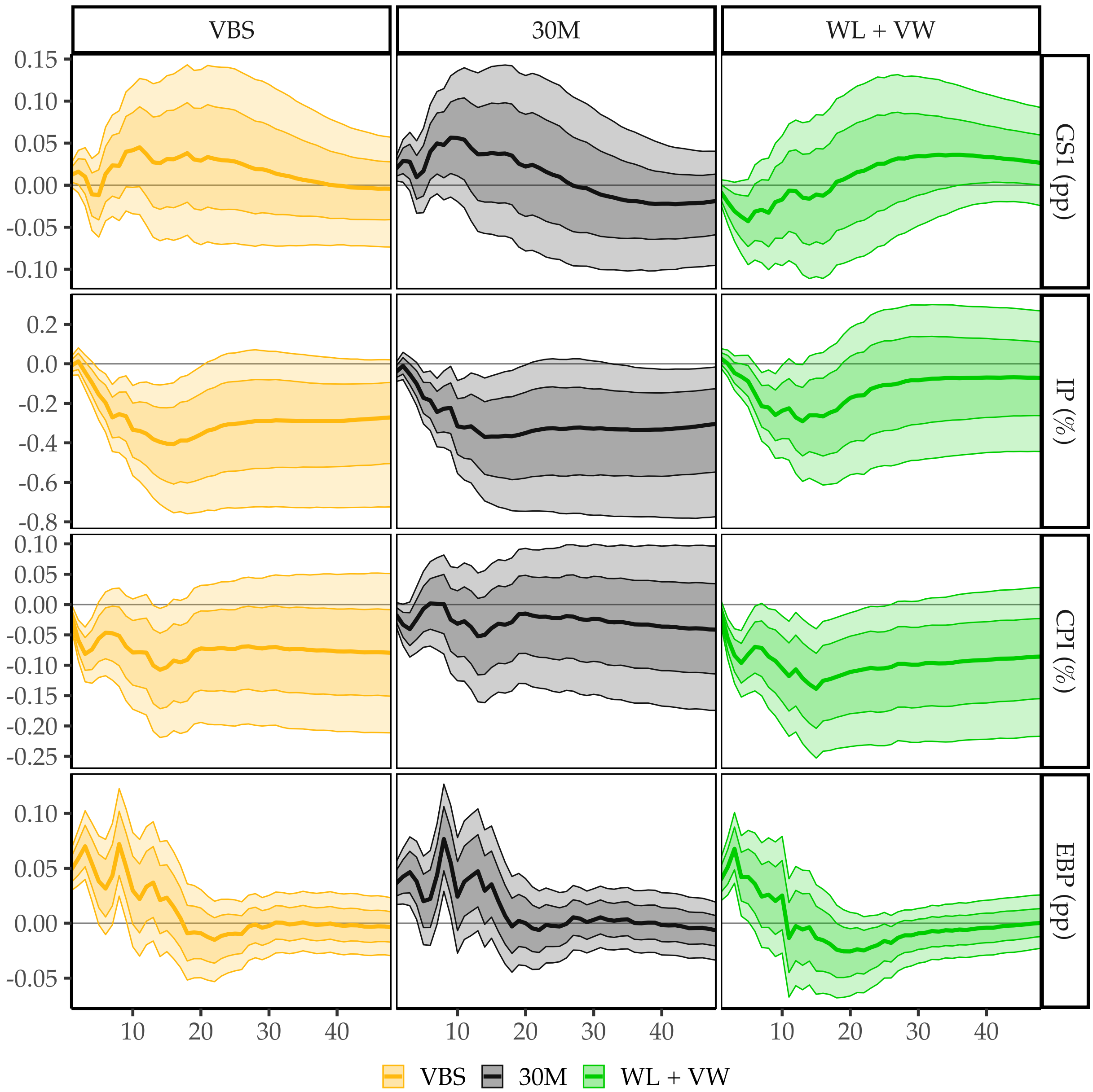
This table reports the estimated AR(12) coefficients of the respective surprise aggregated at the monthly level in months that contain at least one FOMC announcement. This is equivalent to equation (8) in (Miranda-Agrippino and Ricco, 2021).

Figure F.5: Revisiting Figure 10 - Orthogonalized Surprises (Greenbook)



The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-weighted monetary policy surprise, while other column refer to the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. All surprises are orthogonalized to the greenbook forecasts (Miranda-Agrippino and Ricco, 2021). The set of controls includes 12 lags of the monetary policy surprise, 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a Local Projection with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to June 2019 and is at monthly frequency.

Figure F.6: Revisiting Figure 10 - Orthogonalized Surprises (News)



The figure shows impulse response functions of several financial and macroeconomic variables to 1 SD of the respective monetary policy surprise. 'VBS' refers to the volume-weighted monetary policy surprise, while other column refer to the first principal component of the first four Eurodollar futures '30M' the 30-minute window length. All surprises are orthogonalized to the greenbook forecasts (Miranda-Agrippino and Ricco, 2021). The set of controls includes 12 lags of the monetary policy surprise, 1-year Treasury yield (GS1), Industrial Production (IP), Consumer Price Index (CPI) and Excess Bond Premium (EBP). The impulse response functions are obtained from a Local Projection with a lag length of 12 and is estimated using the BVAR toolbox by Ferroni and Canova (2021). The surprise is ordered first and the structural shocks are identified via short-run restrictions. The 68% and 90% credible intervals are based on 10000 draws from the posterior distribution. The sample runs from November 1988 to February 2020 and is at monthly frequency.